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DEVOTED TO

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Vol. CLI.—January-June, 1901.

INDEX.

Aluminum at the Paris Exposition, 1900. (Richards) 107
Amendment to by-laws proposed 397
Andrew Carnegie research fund 397
Annual reception of the Board of Managers to the members of the Franklin Institute 140
Antarctica: A history of Antarctic discovery. (Balch) . . . 241, 321, 413
Asphaltene, etc. (See Peckham)

Balch, Edwin S. Antarctica: A history of Antarctic discovery, 241, 321, 413
Tallow Cave, North Dorset, Vt. 179
Natural Bridge, North Adams, Mass 179
Boiler heating-surface, how should it be calculated 312

Book Notices:
American telephone practice (Miller), 146; Municipal public works (McCullough), 146; Gold mines of Western Australia (Chemin), 146; Power transmitted by electricity (Atkinson), 146; Standard polyphase apparatus and systems (Oudin), 147; Handbook of industrial organic chemistry (Sadtler), 235; Commercial organic analysis (Allen and Matthews), 235; Machinists' and draughtsman's handbook (Lobben), 236; Alternating current phenomena (Steinmetz and Berg), 315; Mesures électriques (Gerard), 315; Laboratory instructions in general chemistry (Congdon), 315; Metal turning (Marshall), 315; Richter's text book of inorganic chemistry (Klinger, Smith and Taggart), 316; Engine tests (Barnes), 395; Dynamo-electric machinery (Sheldon and Mason), 396; Chemisch-calorische Untersuchungen (Jüptner and Toldt), 396; Electric railway motors (Hanchett), 396; Zentrifugal Regulatoren (Bartl), 396; Report of the Geological Survey of North Dakota (Babcock). 471; Experiments arranged for students in general chemistry (Smith and Keller), 471; Encyclopedie des aide-memoire, 471; Traction and transmission, Publishers London Engineering, 471; Fabrication des Liqueurs, etc. (Duplais and Portier), 472; Map of the Anthracite coal fields of Pennsylvania (Ruley), 472; Electric lighting (Crocker), 472; Handbuch der chemischen Technologie (Bolley *et al.*), 473; Technical gas analysis (Bates), 473; Tunneling (Prelini and Hill), 473; Census of Cuba (Sanger, Garnett and Willcox) 473

Central stations, apparatus for power distribution from. (Scott) 282
Christie, James. Flow of metal. (Loss) Discussion 463
Clock, City Hall tower, Philadelphia. (Johnson) 81
Coal mining, electrical apparatus in. (Jackson) 29
Colles, Geo. W. Rotary transformers: their history, theory and characteristics 207, 263, 341, 429

Electrical apparatus in coal mining. (Jackson) 29
Electrical wave propagation. (Pupin) 236
Electrical distribution of power in workshops. Discussion by F. C. Crocker, G. S. Dunn, S. M. Vauclain, Carl Hering, W. H. Tapley . . 1
Electrical progress, recent European. (Hammer) 398
Electro-chemical action. (Reed) 369, 401

Ferrell, Joseph C. A discussion of recent developments in fire-proofing wood 161
Fire-proofing wood. A discussion of recent developments in. (Ferrell), 161
Flow of metal. (Loss) 456

FRANKLIN INSTITUTE:
Annual reception of the Board of Managers 140
Beardsley, Prof. Arthur. Elected an honorary member 474
Committee on Science and the Arts (Reports of):
Reconstructed granite as an insulating material, 78; Facer forged steel car and locomotive wheel, 158; Frizell's method of compressing air with water and method of raising water by compressed air, 159; Moffet & Dobbins's light-projecting glass, 237; General Electric Company's constant-current arc light transformer, 237; Reagan's improvement in grate-bars, 318; Hall's pneumatic clock, 319; Dock's improved threading tool, 319; U. S. standard voting machine, 319; Bardwell's votometer, 319; Humphrey's sawing machine and guide, 319; the Diesel motor, 475; Chester steel tie for railway tracks, 476; National cash register, 476; Indexing reports, appointment of a special committee for . . 476
Sections:
Proceedings of 80, 159, 238, 320, 397, 477, 478
Proceedings of Stated Meetings, December, 1900–May, 1901, ... 77, 147, 236, 316, 396, 474
Drawing School, annual report of the Director 468
School of Machine Design, annual report of Director 469
School of Naval Architecture, report of Director 470

Hammer, W. J. Recent European electrical progress 398
Heating-surface of boilers. How should it be calculated? 312

Incandescent oil lighting, the Washington system 316
Ives, F. E. "Kromskop" system of reproducing colors in photography as applied in pathology 400

Jackson, John Price. Electrical apparatus in coal mining 29
Jennings, Wm. (See Swope) 316
Johnson, Warren S., the Philadelphia City Hall tower clock 81

Kebler, Lyman F. Oil of walnut 394
Kennelly, A. E. Some notable electrical exhibits at the Paris Exposition of 1900 177

Some of the present aspects of physical science . . . 239

Loss, Henrik S. The flow of metal 456

Machinery and the man. (Outerbridge) 464
Marble natural bridge, North Adams, Mass. (Balch) 179
Morris, Charles. Subterranean waters 182

Natural bridge, N. Adams, Mass. (Balch) 179

Oil of walnut. (Kebler) 494
Outerbridge, A. E. Machinery and the man 464

Paris Exposition of 1900. Aluminum at the. (Richards) 107
Some notable electrical exhibits. (Kennelly) . . . 177
Peckham, S. F. Classification of crude petroleums 114
Concerning retene, petrolene and asphaltene 50
Petroleums, crude, classification of. (Peckham) 114
Philadelphia City Hall tower clock. (Johnson) 81
Photographic exhibition, proposed 320, 398
Powder as distinguished from explosives. Essential requisites of. (Williams) 194
Power distribution from central stations, apparatus for. (Scott) 282
Pupin, M. I. Electrical wave propagation 236

Reconstructed granite as an insulating material. Report on 309
Reed, C. J. Electro-chemical action 369, 401
Retene, petrolene and asphaltene, concerning. (Peckham) 50
Richards, Jos. Utilization of wastes from the while metals 445
Richards, Jos. W. Aluminum at the Paris Exposition 107
Rotary transformers: their history, theory and characteristics. (Colles), ... 207, 263, 341, 429

Saturday Night Club of Microscopy 400
Scott, Chas. F. Apparatus for power distribution from central stations, 282
Subterranean waters. (Morris) 182
Swope, J. Newton, and Jennings, W. N. Newly discovered cave at Mapleton, Pa. 316

Tallow cave, North Dorset, Vt., and marble natural bridge, North Adams, Mass. (Balch) 179
Thermodynamics, elementary graphics and geometry of. (Thurston), 62, 124

Thurston, R. H. Elementary graphics and geometry of thermodynamics 62, 124

Utilization of the wastes from the white metals. (Richards) 445

Voting machine. The Bardwell votometer 147

Washington, George. System of incandescent oil lighting 316
Water curtain for protecting buildings from fire 312
White metals, utilization of the wastes from the. (Richards) 445
Williams, W. J. Essential requisites of powder as distinguished from explosives 194

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

Electrical Section—Mechanical and Engineering Section.

Proceedings of the Joint Meeting, held Thursday, November 15, 1900.

MR. JOHN F. ROWLAND, JR., in the Chair.

SUBJECT FOR DISCUSSION:

THE ELECTRIC DISTRIBUTION OF POWER IN WORKSHOPS.

The discussion was opened by PROFESSOR F. B. CROCKER, of Columbia University, New York City, who spoke as follows:

The use of electric motors in factories, mills and other manufacturing establishments has now become so important that it well deserves the careful attention of electrical and mechanical engineers. This new combination of the electrical and mechanical branches of engineering is not much more than five years old, and yet its introduction and success have been so general that it promises to be adopted almost universally in the next five or ten years.

The electric driving of tools and machines must possess important advantages in order to achieve such rapid and general success in its very short career. The principal points of advantage that it possesses may be summed up under the following heads:

(1) *Saving in Power.*—This is generally the first point to be considered, but is by no means the most important, as cost of power in most factories and mills is only 1 to 3 per cent. of the total expenses, the cost of labor being usually many times greater. It is, however, a fact that electric driving usually secures a considerable saving in the consumption of power.

(2) *Cost of Buildings.*—Since heavy overhead shafting is not required for electric driving, the buildings may be made much lighter and cheaper in construction than for ordinary mechanical driving.

(3) *Cost of Equipment.*—The relative expense of equipping a factory with electric motors or with belting and shafting depends upon circumstances, but would usually be greater for the former. The difference, however, is not very great, and the saving in buildings noted above would generally make up the balance. The depreciation on the electrical plant can easily be made less than that on belting and shafting; lubrication is also less and the attention required is no greater.

(4) *Arrangement of Machinery.*—The use of electric motors enables the machinery to be placed in almost any desired position. It is not necessary that they should be parallel or arranged in rows or placed at any particular angle with respect to each other. With belting and shafting, on the other hand, the machinery must be arranged in a very particular manner and very often it has to be placed where the light is poor, and accessibility or other important matters have to be sacrificed.

(5) *Clear Head Room.*—The elimination of overhead belting and shafting by the use of motors gives a clear head room, which enables overhead cranes to be used freely, and also avoids the great obstruction to light and air, which is a serious objection to the old-fashioned methods.

(6) *Cleanliness.*—The dripping of oil from overhead shafting is a constant source of trouble and the dirt thrown out from belting is an even worse enemy to cleanliness. The

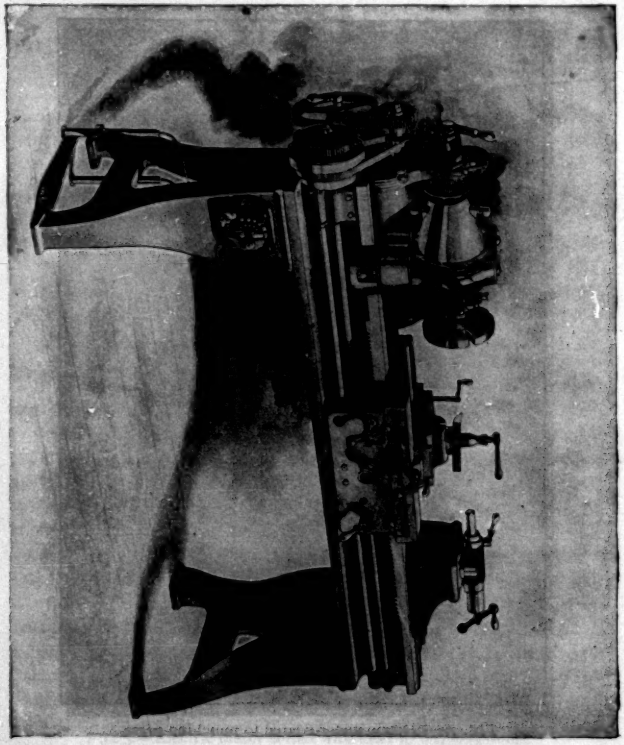

FIG. 1.—Lathe directly driven by electric motor.

agitation of dust by belting and shafting keeps it in constant circulation, so that it penetrates everywhere and everything.

(7) *Health of Employés.*—On account of advantages in regard to light and air and the reduction in dust and dirt, it is found by actual experience that the health of those who work with electrical driving machinery is improved. In the

FIG. 2.—Electric motor geared to punching press.

Government Printing Office in Washington, one of the largest in the world, it was found that the sick list was decreased 20 to 40 per cent. after electric motors were introduced.

(8) *Convenience for Detached Buildings.*—The electrical method enables detached buildings to be reached easily and economically, which is not possible with ordinary methods. The buildings, like the machinery within them, can be

FIG. 3.—Electric motor belted with idler to notching press.

located for general convenience, and not with special regard to supplying them with power.

(9) *Freedom for Growth.*—For similar reasons it is a simple matter to extend a building, or add another in any direction

or at any time as desired, whereas with the old method of driving, the shafting must be installed originally with the idea of extension, or else it must be replaced later. In fact, the length to which shafting can be run is very limited, and the extending of a building, or the erection of another, may require the installation of an additional steam-power plant, which is decidedly objectionable. The electrical plan enables all the power generation to be effected at one point and wherever it is most convenient, even though some distance away.

(10) *Shut-downs Less Frequent and Less Serious.*—An accident in an electrically driven plant usually has a local effect only, simply shutting down one or a few machines, while with belting and shafting the breaking or slipping off of a belt may require the whole or a large portion of the machinery to be stopped, in order to make the repair. In a large establishment a delay of even ten minutes represents a very considerable item in wages, and the interruption of the work is demoralizing. It might be argued that the central plant might break down, but that is just as true of a mechanical installation as of an electrical one.

(11) *Speed Control.*—The variation of speed that is possible with electric driving, and the convenience as well as range of control, are very great advantages with most kinds of machinery. The operator can drive the tool to its limit of capacity, and can on the other hand instantly relieve it of strain, if he finds it necessary. With mechanical driving the means of speed control are far more limited and less convenient than with electric motors. The shifting of the belt on a cone pulley, for example, and the throwing in and out of different sets of gearing is a clumsy operation which a workman is not likely to attempt in order to gain slightly in the efficiency or rapidity of working.

(12) *Increase of Output.*—Owing to the many advantages named above, but especially on account of clear head room for overhead crane service, and convenience of speed control, it is found that the output of manufacturing establishments is materially increased in most cases by the use of electric driving. It is often found that this gain actually

amounts to 20 or 30 per cent. or even more, with the same floor space, machinery and number of workmen. This is the most important advantage of all, because it secures an increase in income without any increase in investment, labor or expense, except perhaps for material. In many cases the output is raised and at the same time the labor item is reduced.

I will now show a number of lantern slides illustrating the various methods of applying and connecting motors to the different kinds of machinery. It will be noticed that no general plan can be followed, since it depends upon the size, shape and character of the apparatus. The many different arrangements may be classed, however, under three general headings: First, *direct connection* of motor and machine, as, for example, when a fan is mounted directly upon the shaft of a motor, or when a motor and pump are directly connected. Second, *connection by means of gearing*, which is often employed when a large reduction in speed is required. Third, *connection by means of belting*, where moderate reduction in speed is sufficient. The flexibility of the belt is sometimes an advantage, since it does not produce the shock upon the motor and wide variations in current which occur with direct connection or gearing. In a punching press, for example, the belting relieves the motor of a large portion of the sudden strain and rush of current to which it would otherwise be subjected.

MR. SAMUEL M. VAUCLAIN, superintendent of the Baldwin Locomotive Works, gave an instructive account of the experiences which he had made in connection with the introduction of electric driving in the shops of that establishment, from the introduction of the great electrically-operated travelling cranes to the finally successful adaptation of independent electric motors to machine tools. Many difficulties were encountered, but in the end all were satisfactorily overcome, and the speaker was now prepared to place on record his cordial endorsement of the modern method, on the score of its many and great advantages over the old style power transmission by lines of shafting, which it is displacing.

The speaker favored belt connections for tools in which there was considerable jar, on account of the elasticity of the method. He pointed out also that machine tools as at present built were not adapted for motors, and in so adapting them he would not alter the structure of the tool so that motor and tool would be one unit, but would provide room so that any motor from the market could be applied as an extra device.

He dwelt at some length upon the important economies in the saving of floor space and in operating expenses which had been realized in the Baldwin works by the introduction of the electric driving system, in testimony of which he made the statement that "if we should abandon electric driving, our manufactured product would now cost us from 20 per cent. to 25 per cent. more for labor;" and again, "were it not for electric driving, the Baldwin Locomotive Works would have to cover 40 per cent. more floor space than they now do, to maintain their present output."

Mr. Vauclain said, in conclusion, that while the question of the saving in power which the adoption of electric motors permitted was of importance, it was by no means the deciding factor, and that he would put in electric driving systems not only if they saved no power, but even if they required several times the power of a shaft and belting system to operate them.

MR. GANO S. DUNN:—It gives me pleasure to participate in this discussion, because I believe one of the greatest engineering advances that have been made in recent years is in course of accomplishing in the introduction of electrical power into our factories, and that by such introduction so greatly will be altered the cost of many kinds of product that we shall experience a readjustment along economic lines that will have important bearings farther than we can see. Already I believe electric power distribution is one of the factors which are enabling American industries to undersell and to give better deliveries than the industries of other countries, and the reasons for this tremendous advantage it indeed behooves us to investigate and to discuss within the widest limits.

I have been particularly impressed with the remarks of Mr. Vauclain, and his statements as to the saving in pay-roll and floor space enjoyed from the use of electric power. Had such testimony been with those of us who in the early days first worked to bring such installations about, our task would have been much easier. Electric power originally based its claim for attention upon the amount of energy saved in the distribution of power from the engine-room of a factory to the work at the tools, and of course included in this advantage the reduction in first cost of power plant in view of the necessity for fewer boilers, smaller engines, etc. There were many factories which introduced electric power because we engaged to save from 20 to 60 per cent. of their coal bills; but such savings as these are not what has caused the tremendous activity in electric power equipment that is to-day spreading all over this country and setting such a standard that the builder who equips his factory at this moment with other than electric power is considered to be behind the times.

A consideration of the question shows that in the largest machine shops and factories the cost of power forms but a small proportion of the cost of the finished product, averaging in fact between 1 and 2 per cent. The argument therefore for electric power based on saving $\frac{1}{8}$ or even $\frac{3}{8}$ of this small item, which would have represented a saving of but a fraction of a per cent. in the cost of the finished product, was not very strong. But those who first introduced electric power on this basis found that they were making other savings than those that had been promised, which might be called indirect savings.

Professor Crocker has so ably enumerated these savings that I shall not repeat them, but I am particularly glad to see them so thoroughly confirmed in what Mr. Vauclain has related to us of the experience of the Baldwin Locomotive Works.

If it is argued the saving of a fraction of a per cent. in the cost of goods from economy in the power item is not of much importance, surely this cannot be said where the savings amount to 20 or 25 per cent. of the whole labor item.

Savings of this kind are enormous. They would pay in many cases for the whole electric equipment in a short period, and it is to these that the present electrical activity in factories is owing.

Without speaking further on the general aspects of the question, I would dwell upon the methods of obtaining adjustability and controllability of speeds, one of the great advantages accompanying electrical power, and will discuss some of the devices that have so far been used for this purpose.

In order not to occupy too much time, I shall refer only to the most important means. Among these are control by armature resistance. This is used in railway practice and for crane service, and other similar duty, characterized by intermittent operation and variable torque. It is effective, but inefficient, since it really operates by varying the voltage at the terminals of the motor, securing this variation by throttling, and thereby wasting, the energy of the operating current; but it is so simple and hardy that it is used very generally wherever the object of control is variable speed as distinguished from fixed speed capable of adjustment, these two types of control being embodied in cranes and lathes respectively.

Control by resistance lacks the feature of stability of speed, or that characteristic of shunt wound electric motors operating at constant potential, by virtue of which they maintain practically constant speed without respect to their load. The methods of control by resistance are so generally known that an allusion to them is here sufficient.

Next comes the system of control by field resistance, which operates by affecting the field strength of shunt wound motors, giving increased speed in proportion to the amount the field is weakened. The reason the speed increases instead of decreasing when the field strength is weakened, is that an essential condition of operation is that the counter electro-motive force of the motor must at all times be nearly equal to the direct electro-motive force of the line. Weakening of the field tends to reduce the counter electro-motive force and compels the motor to increase its speed, to

restore by this means the counter electro-motive force of which it was robbed by the lowering of the field strength.

This system is of maximum efficiency, there being no losses except those in the motor itself, and the field regulator loss, which is insignificant.

It has the very desirable feature of a practically continuous variation over the whole of its range of speed change, the latter being subdivisible into steps indefinitely fine; but it has the following disadvantages:

With the increase of the motor's speed, there is, if the torque demanded remains constant, an exactly proportional increase in the horse-power it is called upon to develop, and yet to meet this increased duty it finds itself possessed of a weaker instead of a stronger field. Should the demand for torque increase, as an accompaniment to the demand for increase of speed, the above condition is aggravated.

The result of these facts is that unless the motor is made very much larger than is required for the actual horse-power demanded by its work, it is subject to internal losses from perturbation of field, to poor regulation and possibility of bucking, and to sparking which would prove destructive.

On the assumption of constant torque and capacity limited by commutation, the limits of successful speed control through the agency of the motor's field are at the extremes of a range of about 33 per cent. increase above a minimum speed. This requires a motor of which the capacity calculated at minimum speed would be about 33⅓ per cent. greater than the horse-power demanded at maximum speed, or about 76 per cent. greater than the horse-power demanded at minimum speed. A given motor, of which the normal speed is the minimum desired, must not be called upon at maximum speed for an output greater than its normal capacity multiplied by the ratio of the minimum speed to the maximum. An example will, perhaps, make the matter clearer.

Given a lathe, in which it is required to increase the cutting speed 33⅓ per cent. without changing the depth of cut or feed. If, at the low cutting speed, the lathe required a motor developing 5·6 horse-power at 850 revolutions per

minute, at the high cutting speed the motor would run at 1,125 revolutions per minute and would develop 7·5 horse-power, and would have to be of a rating of 10 horse-power at 850 revolutions per minute.

Applying our rule in this case, the ratio of minimum to maximum speed is 1 : 1⅓, which is equal to 75 per cent., and 75 per cent. of 10 horse-power is 7½ horse-power. That there is a considerable increase of first cost attending this system is easily seen.

Control by variation of voltage of the circuit is similar in efficiency and in speed characteristics to control by field regulation just described, and for the same conditions of torque and capacity limits, has the enormous advantage of requiring no increase in capacity of the motors.

For obtaining variation of voltage there are a number of methods, among them the connection of two armatures in parallel or in series, or its equivalent, the use of a single armature with two windings and two commutators which may be so connected. With the armatures in series, each receives but half the voltage it receives when in parallel.

The most perfect method of controlling by variation of voltage is the Leonard method, which is embodied in several forms. In the simple Leonard system a motor drives a dynamo which in turn drives the working motor. The variation of the field strength of the dynamo causes its voltage to vary correspondingly, and the speed of the working motor to follow closely these variations. A reversal of voltage reverses also the working motor. If voltage is permitted to remain at a particular value, the speed of the motor will be fixed at a corresponding speed. This method gives beautiful control, so perfect in fact that it is what is used on the battleships of the United States Navy for operating the great turrets and aiming the guns in their horizontal movements. It is possessed of a property by which not only is the motor prevented from falling below the particular speed for which the voltage has been set, but is also prevented from remaining above that speed through the influence of momentum or other causes.

The facility of handling, together with this braking

effect, has led to the adoption of the Leonard systems for operating roll tables in steel mills, and other work of similar character. I have seen an enormous table taken at full speed across a mill and stopped suddenly within a quarter of an inch of a previously made chalk mark, all so smoothly and with such freedom from shock as to seem wonderful.

But the Leonard system has its drawback in its high first cost, although this is considerably offset by a low cost of maintenance. The simple system described requires, besides the working motor, two additional machines of approximately the same capacity as the working motor, and although Mr. Leonard has developed what is known as the "retard and boost" system, which gives similar results with extra machinery of but half the capacity required in his simple system, the first cost is still comparatively high; all of which has resulted in the relegation of the Leonard system to special duties on large and important tools where flexibility of control is of paramount importance.

The most practical system of controlling speeds through the agency of voltage is the establishment throughout a shop of multiple voltage circuits, which maintain permanently six or more fixed voltages of different value, to any one of which the motor may be connected at will.

A system of six fixed voltages may be distributed by four wires, and gives a sufficient number of speeds for most purposes. Where finer subdivisions are required, they may be obtained by a combination of the armature or field resistance methods with the multiple voltage circuits, speeds between those given by the fixed voltages being secured by introducing various amounts of resistance into the armature circuit or by variations in field strength.

For constant torque service, the multiple voltage system requires no increase in the capacity of the working motor, and lends itself particularly well to machine shop practice, in that not all the tools in a shop require adjustable speed.

In fact, if the lighting of a factory is also taken into consideration, probably but one-half of the total load will be of a character best distributed at a fixed voltage, in which

case this part may be served by the outside wires of the 4-wire system, and the intermediate wires, which will be considerably smaller in size, need to be led only to the tools where adjustable speed is in demand.

Without discussing several other little used methods of electrical control of speed, I have now referred to those directly involved in factory distribution. But supplementing these must be used the various mechanical methods of speed changing already well known. Where changes of torque accompany changes of speed, mechanical devices are necessary, unless one is willing to use a motor larger than the size demanded by the power required, to accommodate, when called upon, the increased torques that accompany reductions in speed. A nest of gears or a pair of cone pulleys have the property of increasing torque in proportion to decreasing speed, and in this respect exactly meet the conditions.

They have the disadvantages, however, of requiring stoppage of work for changing speed, which causes a workman, by reason of this inconvenience, often to neglect to change his speed in cases where by so doing he could increase the output of his machine.

As a great deal of the work in factory distribution is of the kind in which torque changes accompany speed changes, the best solution is to use a combination of the mechanical devices, with a reasonable increase in the capacity of the motor. This will give all the advantages of electrical control over a reasonable range of speed, which range may be made applicable to whatever speeds and torques are desired beyond its limits, by adjustments of the mechanical connection ratio.

Mr. Vauclain mentioned that machine tools he would buy with the intention of driving by electric motors, he would not have altered by their builders, but would apply the power from the motors in the same manner as the tools had been designed to have the power supplied by belts. I believe he means this to refer, however, only to the smaller and simpler tools where there are no complicated belting systems. For this class of work I most fully agree with him,

since the ability to use any motor in the market without requiring it built as a special part of the tool enables the user to be independent of particular manufacturers, and gives him the benefit of great reductions in cost.

But in the case of some tools, and particularly large ones which have movable housings to which power must be supplied, the complicated system of belts, bevelled gears, spline shafts, loose pulleys, etc., relegated to oblivion by the attachment of a motor directly to the movable housing built to receive it, creates an advantage which is so obvious as to need only to be mentioned.

To illustrate a machine shop of the old type which we are now leaving behind us, and in which by the way is a large tool of the kind I have just referred to, I will throw upon the screen a view taken not long ago in one of our most important engineering works. You can see there is such a mass of overhead shafting and belting that cranes of any kind are precluded. You can also see how much moving mass there is, the function of which is solely intermediate between the power and its work, and you can see how, by the saving of this overhead gear, a large contribution is made toward offsetting the somewhat greater cost of electrical driving; and it is also not hard to imagine how, with the more compact arrangement of tools and the more perfect facilities for cranes and the handling of their work, together with the greater light and other indirect advantages alluded to by the previous speakers, the Baldwin Locomotive Works has indeed been able to save from 20 to 25 per cent. of its pay-roll as just stated by Mr. Vauclain, and how their floor space would have to be increased 40 per cent. were they to-day to abandon the electric power distribution which he has introduced. Such testimony from so eminent an authority is of the greatest weight, although the savings to which he has referred are not as large as some I know of.

MR. W. H. TAPLEY:—The general and various advantages of the use of electric power in workshops have been so clearly and ably presented to you by the first speaker of the evening, Professor Crocker, that I will confine my remarks to the results we have obtained by the use of electric power

transmission in the Government Printing Office during the past five years.

Our electric equipment consists of:

GENERATORS.

One 300-K. W. Crocker-Wheeler direct connected to Allis Corliss Engine 16 × 30 × 30; speed, 150 revolutions per minute.
One 125-K. W. Crocker-Wheeler direct connected to Allis Corliss Engine 10 × 19 × 30; speed, 150 revolutions per minute.
One 187-K. W. Westinghouse kodak.

612 K. W., or a total of 816 electrical horse-power in station.

MOTOR EQUIPMENT.

		Horse-power.
Belted motors	21	167
Direct connected	22	105
Geared motors	145	375
Elevators	8	127
Hoists	4	80
Total		854

LIGHTING.

Equivalent of 5,000 16 candle-power 50-watt lamps, or 335 electrical horse-power.

HEATING.

		Ampères.
10 press heads:	Starting current	300
	Average running current	70

Average demand for power when everything is in use is about 1,500 ampères × 120 volts = 180 kilowatts = 240 electrical horse-power. This fluctuates between 1,000 and 2,000 ampères, or with a maximum demand of 240 kilowatts, or 320 electrical horse-power, this makes a ratio of electrical horse-power, connected to that called for, of 854 to 320, or 2·67 to 1 for maximum peaks and 3·5 to 1 under average running conditions.

So far, it has not been necessary to have more than the 300-kilowatt generator in service at one time to take care of both lighting and power combined.

Hours in service 1899, 300 kilowatt generator, 2,466.

Hours in service 1899, 125 kilowatt generator, 5,616.

Success of Electric Motors.—The use of electric motors has proven beyond a question of a doubt that they are economi-

cal and absolutely reliable under all conditions when properly designed and installed to meet the work required of them. This success is dependent on the fulfilment of all the details, such us a high grade of wiring, which means good insulation with a substantial protection from mechanical injury. The accessories should be of sufficient size to perform their work satisfactorily, the use of 230 and 500-volt starting-boxes and controllers of equal horse-power should not be used on 115-volt circuits at the same rating, as the increased ampères required by the lower voltage calls for more copper and larger contact surfaces, and unless this is given careful attention, failure will be the result, where it should have been success had these points been taken into consideration.

My experience has been, after an uninterrupted use of circuit breakers for five years on all classes of work connected with our office, that they not only protect the motor, but also the machinery, at the same time keeping down the heavy fluctuations upon the station necessarily resultant from ordinary fuse protection.

Cost of Plant.—Our electric plant consisting of power-house, generators, engines, switchboard complete, including circuit breakers on all feeder circuits, wire in main office and all feeder cables, electric elevators, electric motor equipment with labor and material used in changing from belt to direct connected electric drive, inclusive of lost product of machinery during alterations, cost $150,000.

Cost of Operation.—The amount of help necessary to operate our power plant has been reduced by two engineers over the old belt drive when we operated two engines for power and one for a small electric lighting plant; then, we only ran nights during a session of Congress, while at present our electric plant is in continuous service throughout the year.

The year 1894 being the last before the introduction of electric power, a comparative statement of cost of coal and gas for that year and the last fiscal year, *i. e.*, 1899, shows very clearly for itself a few of the benefits of the electric drive.

	Coal.	Gas.	Total.
1894	$18,284 00	$9,527 13	$27,811 13
1899	4,667 15	947 60	5,614 75
Difference	$13,616 85	$8,579 53	$22,196 38

Electric output during 1894 (lighting only), 218,175 kilowatt hours, as against 644,504 kilowatt hours in 1899 for both lighting and power.

During 1899 the boilers were called upon to heat 1,000,000 cubic feet more of space than in 1894.

The demand for power has more than doubled since 1894.

These results show, since the introduction of electric power, that the cost of help in power plant has not been increased, but slightly reduced, the coal and gas bills have been reduced a total of $22,196.38, notwithstanding the fact that the electric power plant has been called upon to furnish at least 100 per cent. increase of power for mechanical use in the office over the old steam plant, and the incandescent lamps have been increased from 2,000 to 5,000 16 candle-power, and the boilers were called to heat some 1,000,000 cubic feet more of space than in 1894.

The material increase in growth of the office has been close to 25 per cent.; this would mean an increased gas bill in 1899 over that of 1894, together with increased coal bill to safely permit the saving to be increased to a total of $25,000.00.

Our total outlay for the entire electric equipment, previously mentioned, was $150,000. This shows an earning of 16⅔ per cent. on investment, minus 6⅔ per cent. for insurance, taxes and interest, or a clear gain of 10 per cent. on total expenditures from coal and gas bills alone.

This saving directly in coal and gas bills, although considerable, is not the greatest benefit gained from the use of electric power in the Government Printing Office.

Our office has been crowded and overtaxed, all the machinery had to be practically placed in the H Street wing, which was the weakest portion of the building, with a resultant congestion of work that caused delay, and owing

to the disadvantage of handling it, the cost was usually necessarily higher than if they had not been so crowded.

The ability to arrange machinery irrespective of line shaft obtainable under the electric drive made all space equally available and valuable for all classes of work, and not confined to storage as heretofore.

This allowed us to add forty printing presses, which could not be accommodated in our old pressroom, and, although it did not increase the actual floor area, it did materially increase our working floor space.

The individual electric drive most unquestionably increased the output of our printing presses. The foreman of the pressroom told me that during installation he obtained 15 per cent. more work out of his room for the year than under the old belt drive, and that the coming year he expected to get an increase of 20 per cent., if not more. This is not bad from a man convinced almost against himself, having been opposed to trying electric drive, "as it was impossible to make it work as well as steam."

A conservative estimate will allow 10 per cent. as the increase in production from presses after change to electric drive.

The average earning capacity of our presses was $10 each per diem × 100 presses, $1,000; $1,000 × 300 days, $300,000; 10 per cent., $30,000, as a figure that can be placed as a sinking fund to pay for the equipment which, at this rate, should pay for entire electric plant in five years.

The other branches of our work will not show so marked a gain in increased production per capita as the presswork, yet we have been able to increase the output not less than 15 per cent. to 20 per cent. per square foot, with same help, in the mechanical divisions.

This amounts to considerably more than the cost of upkeep and general maintenance of the electric system, which during 1899 was $7,100.

These figures, I feel sure, permit our office to safely say that the benefits derived during the five years that we have been using electric power have financially purchased our entire electrical equipment and maintained it during this

period, and the saving in coal and gas has been paying 10 per cent. on investment after making an allowance of 6·6 per cent. for insurance, taxes and interest.

While our plant may not be as good as if everything were new, the increased cost of material since our purchases were made is more than I would feel justified in working off against the column of depreciation.

Coal consumption, 1899, 2,525 gross tons, which is equivalent to 8·78 pounds coal per kilowatt hour for all coal used in the entire building for heating (4,000,000 cubic feet of space) and manufacturing purposes, in addition to that used in electric plant.

During the months of February, March and April, 1898, we made a test of electric plant isolated from the heating and manufacturing, which resulted as follows:

1898.	Electric Output, Kilowatt Hours.	Coal, Tons.	Lbs. Coal per K. W. H.	Cost K. W. H. at Switchboard.	Total Cost of All Branches Electric Plant.
February.	59,909	81·6	3·05	$0.02.6	$2,426.02
March.	69,990	98·3	3·14	.0203	3,286.66
April.	63,663	94·0	3·30	.022	2,564.00
1899.			This includes Heating and Manufacturing.		
January to December.	644,504	2,525·9	8·78	.0295	32,979.18

We find that it is more economical in the boiler house to operate the entire steam plant as a unit and not disconnect the electric plant.

Periodical checks are made on the electric system alone, yet the running daily commercial test gives us this within a small percentage.

With reference to the cost of current per kilowatt hour, I wish to call attention to the fact that all nightwork receives an increased compensation of 20 per cent. from day labor, all holidays men are allowed double time, and each man is given thirty days leave of absence with pay during the year.

All these labor charges are included in the above table.

MR. W. C. L. EGLIN :—I have listened this evening with pleasure to the many testimonials from users of motors in large numbers, and the many advantages and economies to be gained by their use, so that any remarks from me on this subject would be but a repetition of the experiences of some of the other gentlemen who have just spoken. I will, therefore, confine my remarks more particularly to the installation of motors.

The motors made by the leading manufacturers to-day are very much improved, from a mechanical standpoint, from those with which Mr. Vauclain had so much trouble ten years ago. This is well borne out by the fact that in the Baldwin Locomotive Works one and one-third men take care of all their motors to-day, and, as they have motors of a number of manufacturers, it is now fair to assume that electric motors require less attention than any other form of motor. And, although it is true that the motor has been materially improved, the auxiliaries used in connection with the motor have not advanced with the same progress.

The flimsy construction of the switches, starting boxes and the cutouts, which are in many cases installed to-day, are invariably the cause of many interruptions of service for which the motor is in no way responsible. The arrangement of the wiring is a matter which should be given more careful attention.

With the increase of the size of the individual motors which are now being used, much more satisfactory service could be obtained by the use of a circuit-breaker instead of a fuse.

Personally, I feel that motors should be supplied with controlling equipments similar to those which are used for elevator motors, not necessarily so complicated, as the majority of motors do not have to reverse in speed.

The point which I wish to express is that all the auxiliaries necessary for the operation of the motor should be arranged in a compact form and enclosed firmly in an iron box, the operation of starting and stopping the motor being controlled by a single lever. This controlling lever should be provided with stops so that the motor could not be acci.

dentally started or stopped. In the design of these auxiliaries sufficient material should be employed to make them substantial and able to stand the hard use or abuse which they may receive in practice.

There should be no exposed metal parts carrying current. Provision should also be made so that the conduits will terminate in the controller.

The wires between the motor and the controller should preferably be placed in iron-armored conduit. This iron-armored conduit can now be obtained in a flexible form especially suitable for this class of work.

The increased cost of substantial equipment will be balanced by improved service and reduced cost of maintenance.

I feel that this part of the plant has been the one which has been the most neglected, but which is equally as important as good electrical and mechanical design of the motors.

MR. C. J. DOUGHERTY:—Replying to Mr. Eglin's inquiry in regard to the Greenfield flexible conduit, I wish to say that I have experimented somewhat with this conduit.

I took a sample piece of conduit which contained a twisted pair of No. 16 B & S. gauge wires, and subjected this to rough usage, and also made a test for insulation on the wire after the whole thing had been submerged in water for about forty-eight hours.

I found that the insulation resistance was quite high, and where wire is subjected to a great deal of hard usage, consider that this wire and flexible tubing is a very good article.

We are thinking very seriously of adopting this tube and wire for portable connections in our new machine shop at Cramps' Ship Yard.

Now, in regard to the subject of electrically driven tools, I wish to say that the tool maker and the manufacturer of the electric motor should consult each other in regard to just what they want.

My experience has been that the tool maker in many instances does not fully appreciate the conditions which he desires the motor to fulfil. I make special reference to

tools which are run by compound wound motors. Take, for instance, the case of punches and shears driven by electric motors. When the work is light, the number of punches per minute will exceed the maximum number of punches as specified. When the work is of a heavy character, the number of punches per minute will be about correct.

The tool maker, however, does not consider that there is a considerable variation in speed with the compound wound motor, and that he should distinctly specify what is the average horse-power required of the tool for work done. The tool maker considers that, if he specifies a motor of say 1,050 revolutions, no matter what the horse-power may be, he will still get the 1,050 revolutions irrespective of the power developed. But if sufficient information is given to the maker of the motor, it can be designed to fulfil in every respect all requirements.

DR. A. E. KENNELLY:—There is scarcely a direction of electrical engineering in which there is more scope for careful consideration and good judgment than in the installation of electric motors for driving machinery. There may be special cases in which it may be best to retain the ordinary line shafting and belting. In the majority of instances it will pay to introduce electric motors to some extent at least, and the least first cost consistent with the results desired may in many cases be obtained by the group system, with divided shafting and a motor on each length of shaft. Where, however, the best results of each tool are to be obtained, together with the other advantages incidental to electric driving, the principle may be advantageously carried to its fullest extent, and it may then pay to employ a separate motor for each machine. Every case should be studied upon its own merits and with reference to the character of the work and its output. It would seem, however, that in order to develop the best capabilities of modern machinery, makers of machinery are gradually leaning to the constructions which involve individual direct connection with electric motors.

MR. CARL HERING:—The time which is left is too short to say what I would like to have said in favor of the use of

electric motors for the distribution of power in workshops. I will therefore limit myself to a few words concerning the use of the multiphase induction motor, that is, the non-synchronous alternating current motor, for such work. The induction motor, formerly known as the Tesla motor, has, as is well known, no commutator, brushes, brush holders, etc., and therefore there is no sparking; it is extremely simple in construction, is not liable to get out of order, and requires no attention except oiling. It is easily started with full load, the larger ones requiring for this purpose some simple slide rings, at which, however, there is no commutation and therefore no sparking. It runs at nearly constant speed, and can stand considerable overload. It appears to be an important step toward the ideal motor for use in workshops where it is often put in out-of-the-way places and is taken care of by men who are as a rule not electricians. In a few cases its constant speed is an objection, as for crane work for instance, there being as yet no satisfactory method in use for varying its speed without impairing the efficiency; but such cases are the exception, and the induction motor is in that respect like a line of shafting, which also runs at constant speed, or is supposed to do so.

The ideal workshop system would be to have a motor for each tool or machine, but this is expensive on account of the cost of the motors and of their attendance and repairs. The induction motor goes a step farther toward this ideal than the continuous current motor, as it seems to be smaller, lighter, simpler and cheaper, for the same output and speed, than its rival.

While in Europe this summer I noticed the great progress that has been made there in the introduction of this type of motor. The largest electrical factory in Germany, and perhaps in the world, is equipped entirely with them, and mostly with a motor for each machine or tool. Even the rolling mills of that factory are driven with induction motors. Moreover, the three-phase system as distinguished from the two-phase, is used almost entirely there, especially in Germany and Switzerland. A single textile factory in

Switzerland has 500 such motors. Even some railroads in Switzerland are operated with them.

MR. DUNN:—As this meeting is for the purpose of a discussion of the subjects involved in factory distribution of power, I feel that I would be in the position of assenting to the remarks of my friend Mr. Hering on the superiority of induction motors for factory distribution purposes did I not make some reply.

Contrary to Mr. Hering's view, I consider that so far for factory distribution the direct current motor possesses many advantages over the alternating. For instance, one of the principal requirements of machine shop work is adjustability of speed; in fact, it is to the facility with which electrical motors permit this adjustment that many of the enormous savings we have been discussing are due. It is also a fact that this, in particular, has not yet been accomplished by induction motors. To be on a par with direct current motors in the enjoyment of variability of speed, the frequency of the current as well as the voltage supplied to them would have to vary, since in an induction motor frequency and not voltage controls the speed. Varying the frequency of an alternating current system is impracticable.

Again, the starting torques of induction motors are much less than those of direct current machines, and in such service as crane work and similar kinds of duty, very large starting torques are requisite. Ordinary constant speed induction motors of the kinds built in this country do not develop, at starting, more than from $1\frac{1}{2}$ to 2·2 their normal running torque, whereas direct current motors will easily develop in starting from four to six times their normal running torque. Of this point corroboration may be seen in most recent practice. Plants which have installed alternating current distributions have been obliged also to install alongside of them direct current distributions for the proper handling of cranes and similar machinery.

In spite of the enormous inducements for the employment of alternating motors for railway work, they have been unable to gain a foothold, because of their inadequacy

for the service demanded. It is true, as Mr. Hering has said, that in Europe induction motors are used much more widely than direct current machines, but I have always attributed this to the fact that the direct current motor in Europe was never so well developed as in this country, and consequently has suffered in comparison. The reason for this imperfect development is the custom abroad of building, rather than manufacturing. There, few motors are built alike. Engineers' specifications control the details for almost every plant, and interchangeability or uniformity of type is practically unknown. As a result of building machines by the half dozen instead of by the hundred or thousand, and of the continual changing of designs at the behest of every purchaser according to the often fanciful ideas of his engineer, there have not been evolved such simple and perfect types as this country has produced. I am informed, however, by one who has just returned from abroad, that in England the improvement in direct current motor building, resulting partly from the competition of the American market and partly from the recognition of the great advantages direct current motors possess, is causing a change of opinion as to the relative values of the two motors, and the use of direct current is greatly increasing.

Regarding the question of cost, and Mr. Hering's statement that induction motors are cheaper, I can only call attention to the fact that recent prices actually quoted in this country have been about 25 per cent. higher when the distribution was by alternating current. This difference in price is not due to variations between bidders, since the quotations are from individual companies which make both kinds of apparatus.

The induction motor has advantages in the absence of the commutator and the consequent care that this requires, but the direct current motors of to-day are vastly improved over those of but a few years ago. Great progress has been made without attracting very much attention, since the most prominent engineers have been giving their time to the interesting problems of alternating current. Commutators are made now that will run with but $\frac{1}{64}$ of an inch wear

per year, served by carbon brushes that will operate with a wear of from $\frac{1}{32}$ to $\frac{1}{8}$ of an inch per year, which brings them in point of attention required very close to the commutatorless induction motor.

On the other hand, the extremely small air gaps of the induction motors requisite for the keeping down of the power factor or wattless currents lead them into serious troubles, such as stalling by accumulation of dust and dirt, the overheating of the bearings and even occasionally the bending of shafts by unbalanced magnetic pulls occurring from slight eccentricities, the result of wear or other causes. The induction motor also requires enormous starting currents. I know of a case where the disturbance to the system from this cause is so great that an annunciator has been put in the engine-room with communication to and from each of the motors, so that only one motor may be started at a time on receipt of an answering signal and that the attendant in the engine-room may be advised to "stand by." The torque of an induction motor reduces as the square of the voltage, consequently fluctuations in voltage of the circuits are liable to cause fully loaded motors to fall out of step and stop.

A man connected with an important mining company in the Rocky Mountains supplied with power by one of the well-known alternating current distribution systems in that territory, recently informed me that his company was on the point of throwing out their induction motors, because of the stopping and burning out which occurred from fluctuations of voltage. In mine work copper is not liberally used, making the line losses large. In view of the fact that a 15 per cent. drop of voltage would cause a reduction of torque in the motor of nearly 30 per cent., it is not difficult to understand how a sudden fluctuation of this amount, caused by the starting of some neighboring motor, would cause a motor to lose its grip and stop.

Direct current motors do not take abnormal currents in starting, nor are they affected by wide or sudden variations in voltage.

I do not wish to be understood as pitting alternating

against direct current systems. The day has gone by when such antagonism existed, and now both methods go hand in hand for the accomplishment of a common purpose. I do maintain, however, that for the particular problems of workshop distribution distinguished from transmission and certain kinds of general distribution, the direct current system is preferable for the reasons I have mentioned and for others which there has not been time to discuss.

MR. HERING:—I regret that it is too late to reply as fully as would like to the remarks of my friend Mr. Dunn, who has done such creditable work in building continuous current motors and whose authority on these motors I do not question. He may be right in claiming that the continuous current motor has been developed to greater perfection here than abroad, but on the other hand, it seems, from the statements he made about the induction motors, that the latter are developed to greater perfection abroad than here.

I have already admitted that the constancy of speed is sometimes a drawback, but I still claim that such cases are the exception; it is one of the reasons why it is not so well suited for traction in cities. What I said about the relative costs, weight, etc., was based on statements of a manufacturing company in Germany which makes both kinds. The cosine of the angle of lag of their motors is over 0·9 and the wattless current therefore is not great. Moreover, they will stand 200 per cent. overload and still give their normal output for two-thirds the normal voltage. As for the starting current, I have no data at hand, but I saw some large induction railway motors started with a train of cars and my recollection was that the starting current did not exceed the normal, in fact I think the rule of the motorman was to cut out the starting resistance so as to keep the current about normal.

Mr. Dunn stated that his motors would start with six times normal torque. I doubt whether he or any other maker of continuous current motors would care to have their motors started in practice with such a torque; nor would the circuit breakers or fuses be likely to allow it.

ELECTRICAL SECTION.

Stated Meeting, held Tuesday, January 23, 1900.

ELECTRICAL APPARATUS IN COAL MINING.

By John Price Jackson,
Member of the Institute.

The following paper is intended to give a description of the most important machinery that has been developed by the possibility of using electric power in mines, that is, electric locomotion, cutters and drills. Other apparatus will be merely touched upon.*

Uses to Which Electricity May be Put.—Electricity may economically be utilized in coal mining for lighting, hoisting purposes, pumping, cutting, drilling, running fans, operating breakers or washers, propelling bucket or belt lifts, driving repair shop apparatus, etc. The question as to whether any or all of these applications shall be used is dependent directly upon local conditions. If a system of mines owned by one company are supplied from a central power-house, it is clearly possible to do without local steam plants entirely at the individual mines. Such an arrangement has several advantages: (1) in the matter of economy of fuel; (2) the very great economy in repairs, and (3) a still further economy in working speed efficiency.

Types of Mines.—In dealing with the application of electricity to mining there are several types of workings between which a distinction may well be made. Probably the simplest form will be where the coal lies near the surface, and may therefore be obtained by means of stripping or open workings. In such mines electric drills can be used to great advantage, and electric shovels and cranes will also serve a valuable purpose in getting out the loosened material and loading the cars. If electricity is used for these purposes it may also be economically used for haulage from

* For the illustration of the paper the writer is much indebted to the Jeffery Manufacturing Company for a very complete set of slides.

the mines to the dumps or washers in preference to steam locomotion.

The next class in order of simplicity is where the mineral lies in an approximately level vein appearing on the hillside. In this case a drift or tunnel is run in, and by a system of headers or hallways access may then be readily made to all parts. Such a mine lends itself to the application of electric haulage with unusual ease. Electric drills may here be made of use and also under cutters, shearing machines, etc., if the coal is soft, as in the case of bituminous coal mines.

In the third class it is necessary to use a slope or shaft in order to reach the workings. In this case, in addition to the apparatus which was suggested for the drift, hoisting machinery may also be applied economically. Probably the most difficult variation of the third class is where the vein has a large dip or is badly broken up; under such circumstances the usual method is to run the gangway horizontally at right angles to the vein at the lowest point of the workings. These mines are then worked from the gangway upwards, the loaded cars pulling the empties up the inside planes from the gangway by means of gravity. Such a mine could use electric power for these internal planes to great advantage where the weight of the loaded car cannot be utilized.

The Effect of Number of Openings and Rapidity of Working upon the Efficiency.—In the case of an open mine where the vein is readily accessible, the number of openings is a matter of small moment, but where an expensive shaft, slope or tunnel must be driven before the vein can be worked, methods of reducing the number of openings to a minimum are of great importance when economy of operation is considered. If mules are used for haulage, the length of the gangway from a single opening cannot economically be made more than 1 or 2 miles. This is on account of the large number of mules that would be required to do the work for greater distances. If electric traction be applied, however, the high speed that can be attained and the large loads that may be hauled by a single locomotive render it

possible to extend the gangway to a length of from 4 to 6 or even more miles. Another equally important feature in the working of a great many mines is the rapidity with which the mineral can be taken out. To this result electric haulage lends itself with especially great success. In fact, the length to which a single opening may be extended, even for the most rapid working, where electric haulage is used, is determined almost entirely by the question of its maintenance. In some mines, especially in the anthracite coal regions, the length of gangways cannot be extended indefinitely on account of the large expense in keeping them up. The great natural pressure exerted makes it necessary to heavily timber the passages and also to continually get out material which is forced up from the bottom, and therefore tends to fill the passage.

Electric drills and cutters, as well as pumps, also do much toward the possibility of getting out material rapidly. The number of hand miners in a mine may be multiplied as much as possible, but this will fall far short in output rate compared with a mine of the same size utilizing electrical mining machinery so far as can be done.

Location of Station and Character of Power.—In coal mining the power used for driving the generators will naturally be steam. If a single mine with one opening is operated, the station should be ordinarily located in proximity to the shaft or slope. In this case steam engines may suitably be used for all outside hoisting or elevating purposes, while electricity is employed for all interior mining work. If, as is usually the case, several mines are operated by the same company covering a comparatively large territory, in many instances the most economical arrangement is to locate the power plant at a central position and then distribute electricity, as said before, to a sub-station at each mine opening, which should supply power for all purposes. There is likely to be great economy in such an arrangement, as it permits the centralization of all steam apparatus with a consequent rise in efficiency. In fact, when it comes to actual annual expense in repairs, fuel and cost of attendance, the electrical hoisting apparatus is superior even where the boiler and

engine house are located directly at the mine opening. The local conditions must be carefully studied, however, before the most economical arrangements of the power houses can be determined.

Systems for the Application of Power.—There are two methods of employing electric power in mining, as follows:

(*a*) Direct currents for all power and lighting purposes.

(*b*) Direct currents for haulage and polyphase currents for all other power.

The use of direct current machinery for pumps, fans and cutters has not been found satisfactory in many instances. One of the largest companies operating in the soft coal regions of Pennsylvania, after a thorough trial of such apparatus, rejected it in favor of compressed air. The machinery in a mine is subject to only rare inspection, and that oftentimes by unskilled workmen. The location of the machinery is likely to be the worst possible with respect to water, dust and chemical corrosion. In many cases pumps must be so located that it is impossible to prevent roof drippings from falling upon them. Such drippings are full of impurities, both in solution and granular, of a detrimental character. In fact, the water in a large majority of coal mines contains so much free sulphuric acid as to make it exceedingly destructive to the metal parts of a machine. Such conditions will readily cause electrical troubles in the commutator of the most carefully constructed motor. In so much as the stopping of a pump or fan even for a short time may cause excessive danger or expense, the use of an unstable motor is a serious menace.

Reasons for Installing Electricity.—The uses to which electricity can be put have already been summarized. The reasons for displacing other systems by this form of power are more or less apparent; for instance, the use of mules for hauling wagons from the chambers to the main gangways will probably always be desirable, and in case of mines covering a limited area it might in some instances be undesirable to undertake the expense of installing electric locomotives. But where the main gangway running from the workings to the shaft or slope is more than a mile in length,

the inefficiency of the mule becomes very striking. Mules, with a given number of openings, cannot pull out more than from a third to a half as much total load as can be done by means of electricity. If an endeavor were made to do as large a daily duty, the number of mule trains would become so great as to be entirely unmanageable.

A large number of specific figures from mines which have adopted electric haulage show an average saving over mules of from 5 to 9 cents per ton.

Experience has shown rope haulage to be much inferior to electricity in point of economy, as is now being illustrated by the continual substitution of the latter for the former. The cost of keeping the cable, shives and auxiliary apparatus in repair is an important item of working expense. The actual power required is also much in excess of that called for by electric haulage, and in addition the liability of a breakdown is great. The latter fault is one which will be avoided with the utmost care by a careful operator as it may entail serious expense. In one mine having an output of about 550 tons per day the saving over rope by the substitution of electricity amounted to from 5 to 7 cents per ton. This may be accepted as a fair average.

Compressed air locomotives are being looked upon with some favor by many mining interests, and it must be admitted that there are a number of features in their favor. As such locomotives carry their driving energy stored up upon their own trucks, they obviate the necessity for stringing wires. Moreover, they are not complicated in their mechanism or especially liable to get out of order. On the other hand, machines of this type must be charged each trip or at least at frequent intervals, which consumes time and is more or less cumbersome. They have a decided disadvantage in being of great bulk when constructed for heavy work and also in not having the capability for the high maximum torque which is one of the natural characteristics of the electric motor. Looking at all sides of the question it may be safely said that if electricity is used for other purposes in the mine, electric haulage will be prefer-

able to compressed air, and indeed will usually be the more satisfactory even when compressed air is installed for other work.

For mining pumps, fans, drills, cutters, etc., electricity has to compete with steam and compressed air. The first of these competitors has a firm foothold in the anthracite regions of Pennsylvania. Changes in this region are apt to be very slow on account of the conservatism of the operators. This inertia is sometimes due to lack of the capital required to make radical improvements in the plant, but more often to lack of information concerning improved methods. Probably the most important objection to the use of steam is the rapid deterioration of the timbers near which the pipes pass. The frequent heating and cooling of the damp timbers cause changes in the amount of moisture contained in the wood, which in turn results in quick decay. The piping with its proper covering is expensive, difficult to install, and can only be kept in good condition by constant attention. If the lines are long they are a source of large power loss by radiation and condensation, even when well covered. They are also frequently a nuisance in mines because of their high temperature. Steam engines and pumps are much more expensive than suitable electric apparatus from a standpoint of repairs and attention. Steam cutting and drilling, in most cases, proves unwieldy, since it is difficult to get rid of the exhaust, the difficulty in handling the hot apparatus, and also from the fact that covered steam lines run so far from the shaft, as the workings usually are, would be unwise. For the latter reason power pumps cannot be driven by steam at a very great distance from the openings, which frequently necessitates hauling out the water by mule power. To do this wagons are fitted with water-tight covers, hauled to the "sump," filled by buckets and pulled to the proper point by a team of two or more mules. The slowness and expense of such an operation is self-evident.

The second competitor of electricity, compressed air, is in many respects a much more serious rival. The mechanism of such apparatus is simple and requires little skilled

attention. The repairs and first cost are not great. Moreover, the elements of loss due to radiation and undesirable heat in the mine are absent. But this system, as in the case of steam, requires a large network of pipes. In order to use cutters, drills and pumps, this network must extend from the compressor plant to all parts of the workings. Whenever a section of the mine has been worked out pipes must be relaid to the new sections that are to be opened. The most serious objection to compressed air lies in the fact of its immobility for such changes. In the first place, the cost and trouble experienced in laying the pipe line may be estimated fairly as double that required for stringing wires, and in the second place, after pipes have once been used in a given location and are torn up, they are ordinarily only fit for the scrap heap. This is due to the fact already stated, that the moisture in mines contains much free acid, which will readily attack iron. The effect of this acid is such that when the pipes are torn up they are apt to be found with their threadings completely destroyed, and to be more or less honeycombed and rotten throughout. A compressed air plant must be continually putting in new materials for line work, while in the case of an electric plant the copper wiring may be used over and over indefinitely. The efficiency of compressed air systems from the standpoint of fuel consumption is comparatively low, and, although this may not be a very important matter in coal mining, it should not be overlooked. Still further, though as has been said compressed air machinery is simple and durable, it cannot be compared in these qualities with a well-designed induction motor. The system not being flexible makes it rather undesirable where rapid changes in the points of application require machinery which can be quickly transported or be made to meet a great variety of conditions.

Desirable Pressure to be Employed and Character of Wire Insulation.—Probably the first problem in the design for the electrical installation of a mine will be the determination of a suitable electric pressure. This is dependent upon the possibility of insulating the wires. Considering insulation first,

it may be said in general that it is impossible to put a coating upon the wires which can be depended upon to protect workmen or mules. All insulations that have been tried have sooner or later given out to such an extent as to render accidents liable. Probably the most suitable covering which can be given the wires is a triple braiding of cotton or linen thoroughly impregnated with an insulating weatherproof pitchy compound. After the wires are put up it is also desirable to paint them with two or three coats of this compound. This insulation cannot be depended upon to protect against accidents to life, but it is about the best for the use contemplated. Some mines are wired at least partially with heavy rubber-covered wire, but where the water is bad this is more or less wasteful in first cost, since wire of this character will deteriorate just about as rapidly as the former.

In determining what pressure is desirable it is wise to treat the question as if the wire had no covering at all. In one mine which came under the writer's notice a few months ago, four men were electrocuted within the space of a year, much to the consternation of the operators. The effect has been so great among the people of the region that it is thought not improbable that the system will have to be changed. In this particular mine direct currents of 500 volts pressure were used for haulage and three-phase alternating currents of the same pressure for all other power and lighting purposes. Three of the men were killed by contact with the alternating system, which had insulated wires throughout, and the other from the bare trolley. It has not been at all uncommon for men to be killed by contact with 500-volt trolleys, though ordinarily that voltage has not been considered fatal. At first these deaths were supposed to have been caused from previous heart troubles, but it is now generally accepted that if a man runs his head against the trolley wire while standing on wet rails, death is not unlikely to be the result. Those who have visited mines containing electric plants will appreciate how difficult it is to avoid the wires. The best possible protection must be afforded ignorant miners who cannot appreciate the danger.

With these considerations in view, it may be safely assumed that voltages of not over 250 should be used wherever the mines are not of so great extent as to make the cost of copper excessive, and that where the extent of mines requires 500 volts, special precautions should be taken to protect the workmen. Where alternating currents are used the amounts of power required are not apt to be nearly so great, as they will not be employed for haulage purposes. For this reason it should never be considered desirable to run the pressure above 250 volts. Another reason for this limitation for alternating currents is that they are much more deadly than direct currents of equal voltage. If higher alternating voltage is desirable, it may be transmitted over wires in airways to central points and then be reduced by means of transformers.

Mine Wiring.—It is desirable to next consider what special features are required in the interior wiring of the mines, as it is evident on even a casual thought that the conditions are radically different from those to be found outside. In nearly all mine work pockets of rocks from the roof are apt to fall and carry with them anything so slender as ordinary line work. (It might also be of interest to say in passing that this instability of the roof is the most serious danger to life in a great proportion of mines.) In shafts and slopes any uncovered wire is liable to injury, not only from the natural breaking away of walls, but from the many accidents which occur in regular service. In all parts of the mine the confining spaces, combined with the ignorant class of workmen usually employed, make accidents to the system of wiring, through mere carelessness, difficult to avoid. These considerations render it important that this part of the plant be put in very substantially and carefully. In spite of this, however, the matter has been sadly neglected in a large proportion of the types of plants we are considering. It is not uncommon to find wires thrown over a spike or nail for support, or to see them hooked together at joints in the most careless fashion and swinging loose as though they were clothes lines. Where the writer has visited such mines he has invariably found that the owners were not

greatly pleased with the use of electrical machinery. They said it was too liable to break down.

Trolleys for haulage are put up with much the same fixtures that are to be found in the ordinary overhead work, except that the insulator or switch ears are usually clamped to the wire instead of being soldered, so that the work may be readily torn down and rebuilt. The insulators are fastened to the timbering where possible by means of suitable top plates and lag screws, to iron pipe brackets driven into the wall when the height of roof will permit, or into the rock roof itself. In this last case one method for making the fastening is by using what is equivalent to a short piece of pipe split diagonally. A hole is driven into the roof and the bolt for supporting the insulator is inserted with the head up. The pieces of split pipe are now placed about this so that when they are pushed together endways they shove on their wedge sides and thus expanding take a close grip upon the sides of the hole. This method is also used for fastening the supports for ordinary line insulators. Sometimes wooden wedges are worked in much the same manner. The trolley wire should be arranged with switches every few hundred yards, so that sections can be cut off, when it is necessary to move mules from place to place, or for any other reason. These switches should be encased in weatherproof boxes. In one mine, where the mules stop work in the evening when the last locomotive starts out, the motorman cuts off each section as he goes out, thus permitting the mules to follow immediately. In the morning the mules start in first, and the following motorman cuts in the switches after them. Before the company adopted this scheme many mules were electrocuted, though the pressure was only 250 volts. The mine mule seems very susceptible to the influence of electricity. It would also be well at cross-overs and turnouts to have hanging guards which would warn the miners of danger.

The return circuit should be made just as substantially, by means of a proper bonding of the track, as would be done in a well-equipped passenger railway system. Where pipes run near the tracks they should be carefully connected

at short intervals to this return circuit by means of substantial copper wire taps. Failure to do this has caused the destruction of much piping, due to electrolytic action.

Feed wires are supported on porcelain insulation of the ordinary type if fastened to the wall; if fastened to the roof they should be especially arranged. In one form the moisture is drained down a pin and passes through a hole in its center to the bottom of the insulator, where it drops off, thus leaving a dry surface about the wire. Branches or sub-feeders should have cut-off switches and fuses. The wires should be run so far as possible in airways or abandoned gangways, under which circumstances both the wires and the miners are protected. When feeders run down shafts or slopes, or in places liable to disturbances, they should be put in strong iron-armored conduit. Wherever they are so placed as to cause dangers to workmen they should be sheathed either by wooden boxing or conduit.

Electric Locomotives.—Having now dealt at some length with the conditions to be met in utilizing electric mine power and the requisites for its distribution, we are ready to consider a few of the features of the machines that do the work. The electric locomotives used in mines are similar, in a general way, in their electric features of design and control to the equipments found in street railway service. They are much modified in detail, however, by the fact that they must be able to pass through gangways as low as 40 inches, must pull heavy loads, must withstand rough handling by unskilled labor, must run from very low to very high speed, and must be so arranged that the motorman has very ready control. The last condition is more important in mine work than in any other class of haulage, as the motor runs in locations where the track is liable to be obstructed at any time by falling rocks or a stray car. Since such obstructions, due to the numerous curves found in most gangways, will frequently not be seen until the motor is within a few feet, the necessity for quick and absolute control becomes obvious. The control depends upon three elements: the method of regulating the motor; the system of brakes; and the arrangement of controlling levers with

reference to the motorman's seat. Another subsidiary element, but in many ways vital, is the sand-box. As a rule much moisture is to be found in mines, and the rails are, therefore, exceptionally slippery. This condition evidently calls for efficient sand arrangements. Commonly four sand spouts are used, one for either track at both ends of the car.

Description of Locomotives.—The base upon which the mining locomotive is built is an exceedingly heavy iron frame containing supports for the wheel boxes, and extending downwards to within 4 or 5 inches of the track. In some locomotives the wheels are placed outside of their boxes and this frame; for ordinary practice they are within. The number of wheels is usually four, though at present a few large locomotives are being designed with three pairs. On two or three axles, as the case may be, are placed the motors. These motors are of the waterproof street railway type, and vary from 15 to 50 horse-power capacity each. They are supported at one end through bearings on the wheel axles, and at the other by means of suspension springs. Heavy brakes of the steam locomotive type are placed upon each of the wheels. Sand-boxes are arranged as already explained. A headlight is placed at each end of the frame, and both are expected to burn continuously when the locomotive is in operation. These headlights usually consist of a cast-iron box with reflector and protecting screen, and containing a sufficient number of incandescent lamps in series to use up the impressed pressure. The headlights should be on separate circuits. A better and far more efficient plan is to use enclosed arcs instead of incandescent lamps, with the proper amount of resistance in series. The added safety attained by the use of such a headlight will well repay the extra expense in power used. The controller is similar to the ordinary street car controller, except that the resistances are heavier to enable them to safely carry the excessive overloads which are frequently developed. This resistance, which is usually in the form of iron sheets with mica insulation, is packed away on the frame between the motors. The trolley wheel is of the ordinary type. The trolley pole is about 4 feet long, and is set in a socket at

either side of the locomotive, on a swivel, and is so arranged by springs that it will follow the trolley from 4 to 5 inches above the deck of the car to a vertical position. If the pole is of iron it should be thoroughly insulated, as it must be handled frequently by the motorman. The motorman's seat is usually placed at only one end, in which case the locomotive is called a "single-ender." Sometimes a seat is placed at each end or in the middle between the axles, which constitutes a "double-ender." The latter form is especially desirable, as the heavy frame surrounding the motorman protects him from accident. The brake-wheel should be placed conveniently to the motorman's right hand, the controller handle to his left, the sand-box lever to either hand or to the left foot, and the reversing and cut-out switches to the left hand. The proper arrangement of these details is of great importance to the success of the machine. The heavy frame and all the apparatus contained on it should be supported upon the wheel axle boxes through spiral or carriage springs. If this is not done efficiently the great weight of the locomotive will cause heavy track repairs by its severe pounding. The wiring, which is encased in strong canvas hose, must be supported firmly to prevent abrasion of the insulation. All levers or portions of the apparatus should be kept at least 6 inches above the level of the tracks, and should be protected by the apron of the heavy iron frame. All the apparatus should be closely covered to prevent the entrance of moisture and dirt. In doing this, however, provision must be made for the escape of heat from the rheostats.

The weights of locomotives vary from 4,000 to 30,000 or even 40,000 pounds. A 12,000-pound machine would have about the following proportions: draw-bar pull on the level, 1,500 pounds; speed, 6 to 10 miles per hour; two 20 horse-power motors; a minimum gauge of from 27 to 30 inches; minimum width over all, 48 to 50 inches; minimum height of from 36 to 40 inches; length, excluding bumpers, from 9 to 12 feet; wheel base, from 40 to 55 inches; diameter of wheels, from 28 to 30 inches. A 24,000-pound locomotive would have a draw-bar pull of about 4,500 pounds; 6 to 10

miles speed; two motors of 50 horse-power each; gauge of from 35 to 40 inches; outside width of from 58 to 65 inches; height of from 38 to 45 inches; total length of from 11 to 12 feet; wheel base length, from 40 to 56 inches; and diameter of wheel from 28 to 30 inches. The minimum weight of rails that can be used satisfactorily varies from 8 pounds per yard for a 2-ton locomotive to 40 pounds for the heaviest. Mines using from 12,000 to 16,000-pound machines should, under ordinary conditions, use about a 30-pound rail. Where exceptionally heavy service is encountered the adoption of 60-pound rails is meeting with favor. The draw-bar pulls are given for running on the level. On an up grade the pull will be reduced on account of the locomotive having to pull up its own weight. The element of the force of gravity tending to pull the car down hill, and which therefore must be overcome, is approximately one hundredth of the total weight for each per cent. grade. This would be equivalent to a draw-bar pull of 20 pounds per ton. In the case of the 12,000-pound locomotive given above the draw-bar pull on a 5 per cent. grade would thus be reduced from 1,500 to 900 pounds.

The Hauling Power of Locomotives.—The number of tons a locomotive can pull over a given maximum grade will be dependent largely upon the character of the wagons and the tracks. If the wagons have loose wheels on fixed axles and are in first-class condition, the actual friction per ton of gross weight may reach a minimum limit of 20 pounds, though even under these conditions 30 pounds will usually be nearer the correct figure to use. On the other hand, if the wagon wheel bearings are badly worn or the track is much out of alignment, the tractional coëfficient may reach even as high a figure as 70 or 80 pounds. To determine the size of locomotive required for a given mine, the first thing to be known is the maximum or limiting grade over which the load must be hauled. Next the tractional or frictional coëfficient must be determined as nearly as possible by inspection of the wagons and roadbed, or any other data available. If this coëfficient plus 20 pounds, multiplied by the per cent. grade, be divided into the loco-

motive draw-bar pull for the given grade, the result will be the number of gross tons that can be hauled in addition to the weight of the locomotive. For instance, suppose the 6-ton locomotive before considered is to operate in a mine having first-class track and cars and a maximum grade of 2 per cent. against the load. The draw-bar pull at this grade will be 1,260 pounds. The force to be exerted against the grade will be 40 pounds per ton, and that required to overcome friction 30 pounds, making a total resistance of 70 pounds per ton. This divided into 1,260 equals 18, or 18 gross tons can be hauled.

Electric Cutters.—Electric cutters are designed primarily to cut soft material such as bituminous coal, though it ought to be possible to modify them for satisfactory use in harder materials. The material on which these machines are used is seldom of a uniform nature, as the soft coal veins are more or less polluted by "clay" veins. These clay veins are extremely hard and difficult to cut. A machine to operate successfully under such conditions must be constructed with great mechanical rigidity; also the electric equipment and its control must be made to withstand extreme overloads and shocks. The cutter is usually designed to undercut the mineral vein and is then called an undercutter, though it is also made for a vertical cut, in which case it is called a shearing machine.

Chain and Bar Cutters.—The cutting may be accomplished in the chain machine by having a large number of blades attached to the periphery of a sprocket chain which revolves about a large sprocket at the cutting end of the machine. The chain is driven by another sprocket at the rear of the machine, which is connected, through a series of gear wheels, to the motor. This chain cutter system, with its motor complete, is arranged so that it will move forward 6 or 7 feet on the tracks of a base upon which it is mounted. The end of the chain which passes around the large wheel is so arranged that when the blades or cutters are pushed against a wall they will cut a clear path for the wheel, bearings, etc., to follow. The base upon which the cutter proper slides is braced firmly to the walls and the roof by

means of jacks. The relative speed of the feed along the tracks and of the chain cannot ordinarily be changed, but the positive speed of both should be controlled by a proper motor regulator, so that when the cutters are passing through different types of material suitable speeds may be maintained. The truck by which this motor is moved from room to room is specially constructed with rails and chain block, so that it may be loaded and unloaded readily. These trucks are sometimes also arranged so they may be geared up to the motor after it is loaded, thus making it self-propelling. Such an arrangement is highly advisable, as the apparatus is heavy and difficult to move by hand or mule power.

The direct current motor is not nearly so satisfactory for a machine of this type as is the alternating current induction motor. If used it should be of the shunt type and should be designed to stand an overload of 100 per cent. for short times without injury. The controller should be of heavy resistance, capable of withstanding an equal overload. Under no circumstance should a starting-box only be used. For starting polyphase induction motors the ordinary methods of changing the resistance in the armature or of using an auto-transformer in the fields are satisfactory.

To operate a chain undercutter the machine on its truck is hauled into the room on the wagon tracks and placed with its cutters next the face of coal to be cut, and on the left-hand side of the room. It is there run off its truck and jacked firmly in place. A fixible cable, almost 100 yards long, is used for connecting it with the mains. Two men are required, a runner and a helper. The runner has charge of the machine, starting and stopping it, and keeping it in good condition. The helper shovels back the cuttings, and assists in moving and jacking the machine. Having set up the machine, it should be able to make a cut about 6 feet deep and 45 inches wide, with a kerf of from 4½ to 5½ inches in from three to five minutes. When the machine has fed itself in to its full depth it either reverses itself or is reversed by hand. The time of withdrawal is about one minute. Having been withdrawn, the machine is moved over

and made ready for another cut. A cutter of this type should be able to cut from 100 to 300 linear feet of coal face per day, 6 feet in depth, the actual amount being determined by the seam and the number of moves that must be made.

The dimensions of a cutter of this type vary from about 18 to 30 inches in height over all, making a cut in width from 40 to 45 inches, and from 5 to 7 feet deep. The capacity of the motors used is from 8 to 16 horse-power. The low machines can be used in veins from 2 to 3 feet in thickness or higher. The great trouble with coal cutters in the past has been their mechanical construction. They have been found, in many instances, when striking a stiff clay vein, to so wedge into the kerf as to require digging out with a pick and shovel. The heavy service has frequently caused such great repairs and so many delays from mechanical breakages as to make the machines uneconomical. Also lack of stability and simplicity in the details of the electrical construction have caused serious annoyance and delay. These difficulties can be overcome.

Cutter-bar machines are similar in their general construction to the chain machines, except that the knives are placed on a horizontal bar, which rotates and cuts into the wall. The arrangement is a little like that of a wood planer. These machines are being superseded by the chain type, as they are apt to clog with the cuttings and in other ways are not as satisfactory.

Longwall Machines.—The longwall system is another method of machine mining. In this system one or two rails are laid along the coal face to be cut and the machine is fed along this by a suitable cable arrangement or gear and pinion. In this machine, instead of using a chain, the cutters are placed upon the periphery of a large wheel which extends out from the side of the base into the wall to be cut. The motor for this machine should be similar to those used in the machines just described, but should be of somewhat greater power—from 15 to 25 horse-power. The cutting wheels may be made to cut into the face to a depth of from 3 to 5 feet, making a kerf of from 4 to 5 inches. The

wheel must be arranged to deflect slightly on an axis at right angles to the wall, in order that it may take the variations of the bottom. These machines can be made to cut through soft coal at as high a rate as 25 inches per minute, but should have a variable feed speed so that the rate may be made as required by the character of the material cut. The feed rail must be firmly jacked between the roof and floor.

Shearing Machines.—Sometimes it is found desirable, on account of formations in the mines, to make a vertical instead of a horizontal cut. For this purpose a shearing machine is used. This machine is similar to the chain undercutter, except that the cutting chain runs in a vertical plane and can be raised or lowered to suit conditions. To provide suitable supports for holding the machine at any height on the vein, it is clamped to two or more rigid columns which are jacked between the roof and bottom. To make a cut, the machine is first placed at the top, and the cutters run to their depth; they are then withdrawn and the machine lowered for another cut. This is continued until the whole thickness of the vein has been sheared. The width of a cut is from 30 to 40 inches and the depth from 5 to 7 feet.

The chains and cutters of these various machines bear the largest strain and must therefore be given special attention. If the bits are permitted to grow dull, the machine may use from two to three times more power than necessary and will give great annoyance. The number of bits on a chain will vary from 35 to 50. The advantages of coal-cutting machines are about as follows: A saving in wages in mines of from one-fourth to one-half, or an increase in the output of the mines to the same extent; the total saving in the cost of mining and placing on car in mine room, nearly one-half of that required in pick mining; and an increase in lump coal of from 3 to 5 per cent.

Electric Drills.—Electric drills may be used in all mines whatever the material to be dealt with. If the material is very hard a reciprocating drill must be used, but for coal

mining an auger or rotary drill proves most efficient. This serves to displace the hand augers which have been used heretofore in blasting out the material. The motor must be of very light construction ; in fact, efficiency should be sacrificed to give the least possible weight in the design. From 1 to 1½ horse-power gives sufficient capacity. The construction must be as rigid as in the case of the cutters previously described. The mechanism may be divided into two types, that is, geared and direct-connected. In the former the motor is geared down to the natural speed of that of the drill, while in the latter the weight in the motor is sacrificed so that its armature can be mounted directly upon the spindle holding the bit. The former construction is the more complicated, but the latter is heavier. Under all circumstances the design should be so made that the complete apparatus can be readily handled by not more than two men. The motor with its spindle is so arranged that it can be clamped upon an upright post through the intermediary of a swivel joint, which will permit turning it at any angle. It must also be possible to move it up and down along the post, the two movements combining to make it applicable to any situation. Such a drill should be able to drill from six to eight times as rapidly as a man with a hand borer.

Electrical Pumps.—The remaining important classes of electrical apparatus used in coal mining, namely, pumps, hoisters and fans, are of the same general characteristics as are those to be found in other industries, so that we will only give them a cursory glance, pointing out a few important points. So far as possible in mining, the workings are arranged so as to permit the water to flow by gravity from the workings to the foot of the shaft, where, as a rule, it is pumped out by large steam apparatus. Insomuch as it is impossible to often run all the water by gravity to this point, a number of additional stationary pumps must be placed at various points. The latter must be of the compressed air or electric type, and if electricity is used, the former should also be driven by it. The objections to compressed air and steam have already been stated, but there is the added

objection to the steam shaft pump as frequently used in the low economy when compared with its brother, the electric power pump. There is another class of pumps which is strictly a mining type; this is the portable pump. In a mine of great extent there are apt to be numerous small pockets in which the water collects, but which are not important enough to call for the installation of a stationary pump. It is not uncommon, as has already been stated, to haul the water from these pockets in wagons. The portable pump has been developed to obviate the expense of such work. Such a piece of apparatus consists of a small duplex or triplex power pump driven by a small direct current or polyphase motor, and mounted upon an exceedingly rigid truck. The truck must be of such strong construction as to prevent serious vibration. In using such a pump the water is dammed up in unused gangways or other spaces, until quite a body has collected. The pump is then brought to that point and the water cleaned out. By this means a single pump may be readily used to keep a large area of the mine dry. A pump of this character connects to the power feeders by a coil of flexible wire, and carries its controller, switch, fuses, etc., on the truck. The truck itself may be made self-propelling, if a direct current motor is used, by the addition of a trolley pole. This is quite a convenience sometimes. The best form of pump for mining purposes in general is one of substantial horizontal duplex form. The vertical pumps, as a rule, are too scantily built, in order to make them of low enough height, to be satisfactory for such work. The motor should be of slow speed, with simple gear arrangements for driving the crank rod, preferably using a worm mechanism.

Electric Hoisters and Fans.—The hoisters for use in mines and driven by electricity are exactly like those for connection to a steam engine. In addition to the economy of the former over the latter, the one striking advantage is the possibility of using absolutely sure automatic braking devices. By means of a suitable solenoid attachment to the brake-band it is readily possible to have the brake go on whenever the current is off, whether due to broken con-

nection or regular service; also to have the brake automatically act when the speed exceeds a given maximum. The comparative efficiency of the steam hoisting engine as ordinarily used, and the electric motor supplied by a first-class generating plant, is well known to you all; the latter use from one-third to one-half as much energy as the former, if not less. In this particular application the direct current motor probably has a little advantage on account of its large torque when built of the series type, but the modern well-designed polyphase motor will meet requirements even in this regard, and has so many additional characteristics of stability as to make it superior.

The use of fans in mine is much facilitated by the application of electricity, since they can be placed all over the interior, as well as outside, with very little expense other than the original cost of the fan itself. Where electric power is not available it is frequently found necessary to use hand fans in some of the distant workings, or construct airways at excessive expense. These fans are of the regular ventilating type to be seen in any large building and need no description.

Suitable Superintendents.—Before closing, I wish to make one remark in regard to the present practice of employing engineers or superintendents for mining power plants. After a variety of experience in inspecting and testing a large number of equipments of this character, the writer has become convinced that mine operators must take a different step in reference to superintendence or they will lose much of the advantage of their plants. The ordinary method now is to break in some especially bright young miner, let him learn as he can some of the important duties required in taking care of such a plant, and then put him in charge with possibly a few other boys to help him. Such is not uncommonly the case where even as much as 500 to 1,000 kilowatts of electrical energy are installed. The salary paid is, of course, entirely too low to attract a properly trained man. The result of this saving in the superintendent has been much stoppage and consequent decrease in output, heavy repair bills and a rapidly

depreciating plant. It is fair to assume that this machinery, which is even more difficult to operate properly than a street railway or transmission plant on the surface, should have a thoroughly well trained electrical engineer at its head. If the mine owners of the country should heed this one suggestion practically all the difficulties now experienced in electric mining equipments would be abolished.

State College, Pennsylvania,
January, 1900.

CONCERNING RETENE, PETROLENE AND ASPHALTENE.

By S. F. Peckham.

The persistent use of the word retene, or retine, and more especially of the words petrolene and asphaltene, in current literature relating to solid bitumens and bituminous minerals, leads me at this time to offer a protest against their further use, with reasons therefor somewhat *in extenso*.

The prominent position which Mr. Edward J. De Smedt has held in reference to asphalt paving in the United States has given his opinions great weight among those engaged in that industry. In 1893 he published in *Paving* a remarkable paper, which he said was designed "to open a discussion and investigation in regard to the required qualities of asphalt to form the best pavement." After making statements in reference to bitumens in general, he proceeded to make a few rather sweeping assertions, which may be carefully considered. He says: "Bitumens are generally composed of three different hydrocarbons: (1) retine, (2) petrolene, (3) asphaltene. The knowledge of these compounds is due to the important investigations of Messrs. Le Bel and Muntz." "Retine—C, 78·84; H, 10·22; S, 10·78—is soluble in alcohol; submitted to heat, it gives off hydrogen sulphuret, marcaptan, and liquid hydrocarbon,

and some coke is left. This compound is not desirable in asphalt.

"Petrolene—C, 80·60; H, 10·20; S, 9·20—is soluble in ether, and is the most important and desirable compound in asphalt for paving purposes, since it is the compound which gives the viscous adhesive qualities to asphalt.

"Asphaltene—C, 78·00; H, 8·83; S, 12·89—is not soluble in alcohol or ether, but is soluble in chloroform and in bisulphide of carbon. It is this compound which gives hardness to asphalt, and the more asphaltene an asphalt contains, the more brittle and hard it is. So an excess of asphaltene is detrimental in asphalt employed for paving purposes."[1]

As the technical considerations involved in De Smedt's paper were met in a masterly manner by Captain Dolphus Torrey in a paper published in *Paving* in March, 1894, I shall not further refer to that aspect of the subject. De Smedt was very unfortunate in his manner of conducting the discussion, and it soon fell for want of cohesion.

When De Smedt's paper was published, I was in California and was not reading *Paving*. I was, however, soon brought in contact with the practical effects of this publication. As chemist to the Union Oil Company, of California, I was asked to determine the amount of retene in their products, and in correspondence I began to receive memoranda of determinations of retene. The name retene had been for many years applied to a crystallizable body soluble in alcohol which was derived from several varieties of fossil resin. As it is crystallizable, its formula had been carefully determined to be $C_{18}H_{18}$ or some other multiple of CH. A great number and variety of different compounds derived from it had also been analyzed. There has been no question about the composition and relations of retene for years as described in the general and periodical literature of chemistry. When I was asked to determine the amount of retene in an asphaltic residuum from California petroleum, and learned that a great many determinations of retene were being reported as made from asphaltum from many localities in differ-

ent parts of the world, I began to wonder what had happened.

At last a prospective purchaser of California products requested us to ascertain the amount of objectionable retene contained in our material, and I set to work to make the determination. I had previously learned that methyl alcohol dissolves a certain percentage of our product, ethyl alcohol dissolves more, and amyl alcohol still more. By prolonged boiling in 95 per cent. ethyl alcohol nearly as large a percentage was dissolved as in ethyl ether or petroleum ether. No crystallizable body could be obtained from any of these solutions, and I discovered that by varying the strength of the alcohols and the temperature at which they acted, the proportion of the residuum dissolved could be varied indefinitely. Further experiments upon crude California and other asphaltums give similar results.

Later, I was asked by a friend, who was in correspondence with a chemist *in re* retene, or retine, I don't know which, if I had made any determinations of that constituent of asphalts. I related the facts as given above and suggested that the correspondent be asked, if he had obtained any crystallizable retene from any asphaltum, to tell how he did it. He replied that he had never determined retene, nor had he ever obtained a crystalline compound from any alcoholic solution of asphaltum. This experience confirms my own.

As to the word retine, I have made an exhaustive search of the dictionaries of several modern languages, as well as English, and can find only one word with that spelling. That is the French word which is equivalent to our word retina, as applied to the eye.

If I understand De Smedt, he refers to the researches of Le Bel and Muntz as his authority for what he says *in re* retene, or retine. I have never seen any memoir, by either or both of these gentlemen, wherein any reference is made to any such substance, or, in fact, to any alcoholic solution obtained from bitumen.

Captain Torrey has written quite *in extenso* upon the alcohol soluble from Trinidad pitch. All that he has pub-

lished upon the subject is to be found in *Paving*.[2] He has very carefully conducted a large number and variety of experiments upon this alcohol soluble. He has discovered and recognized the differences produced by varying the strength and temperature of the alcohol, and he seeks to counteract their disturbing influence by what he calls a *time limit*. He allows the alcohol to act in exact periods of time, which he seems to think will give exact results. I do not think he can escape the relations of strength and temperature in any such manner, nor do I see any occasion for it, unless the petroleum ether soluble can be divided by using absolute alcohol at some fixed temperature. What is wanted is an absolute factor that can be repeatedly determined in the same specimen within reasonable limits; or, in language lately used by Dr. S. P. Sadtler, "What is wanted is a study of the action of a series of solvents of fixed purity upon different natural bitumens."[3]

One curious practical illustration of the use which has been made of this name is found in an "Asphalt Hand-Book," issued by the Standard Asphalt Company, of California. Dr. F. Salathé made an examination of their crude asphalt, and finding that acetone would dissolve more of it than petroleum ether, he made an acetone soluble and called it "Petrolene (retenoid)." The portion insoluble in acetone he called "Asphaltene (retine)." He further gives the "combined sulphur (chemically held in bitumens)" as 0·73 per cent. What meaning did Dr. Salathé attach to the word "retine" as used here? De Smedt's retine had 10·78 per cent. of sulphur and his asphaltene has 12·89 per cent. Did he intend that these substances are practically identical? Moreover, De Smedt's petrolene has 9·20 per cent. of sulphur; therefore, according to De Smedt, the California asphaltum should contain:

			Per Cent.
Petrolene	67·50	Sulphur	6·21
Asphaltene	32·50	"	4·18
	100·00	"	10·39

Dr. Salathé reports the content of sulphur to be 0·73 per

cent. No more striking illustration can be found of the use of words that have no meaning.

So far as I am acquainted with the literature of asphaltum, it is not clear who first applied that name petrolene to that portion of asphaltum that may be soluble in ethyl ether or petroleum spirit. In the exhaustive work of Alfred H. Allen, upon "Commercial Organic Analysis" (Vol. II, page 374), published in 1886, mention is made of Boussingault's separation of asphaltum into "petrolene" and "asphaltene," but no further reference to the use of these names is made. It is possible that De Smedt first used that method of analysis and applied the names as they have since been used, but apparently we are indebted to Mr. Clifford Richardson for their use.

Their use has proceeded of late years upon a totally erroneous conception of the constitution of asphaltic minerals and their relation to each other. If the arbitrary use of these names had been confined to Trinidad pitch, and the method or procedure of analysis of which they form a means of expression had been confined to the admitted determinations of the location of the spot upon the Island of Trinidad from which any given specimen came, less confusion would have arisen than has followed the attempt to designate many different things by one name. In a general way, it may be correctly said that there are no two asphaltums from different, widely-separated localities that are alike. If the same proportion to a $\frac{1}{1000}$ of a per cent. is soluble in any of the solvents of bitumen, it does not establish the identity of the two specimens. There has been nothing approaching the exactness demanded in chemical science observed in the use of the word petrolene. Ethyl ether, petroleum ether and acetone have all been used as it suited the convenience of the experimenter, and the percentage dissolved has been called petrolene, and various assertions have been made concerning petrolene and the relative value of asphaltums containing much or less of it; when at the same time the material dissolved from one asphaltum is one thing, and that dissolved from another asphaltum is quite another thing, and the different proportions of material dis

solved from the same asphaltum by different menstrua are equally different. It is obvious that much that has been said in reference to petrolene applies with equal force to asphaltene. The names have been applied to various residues soluble and insoluble in various menstrua, and in various proportions. These residues possess various physical and chemical properties, and are in few respects identical. The name asphaltene has been used to designate that portion of Trinidad pitch that is alone soluble in carbon disulphide. Mr. Richardson admitted, in his testimony given in the Peoria trial, that carbon disulphide did not dissolve the bitumen in Trinidad pitch within 1 per cent., and Messrs. Wallace and Whinery, on the same occasion, described the material dissolved in this manner as an inert substance, without cohesion, and playing the same part in a paving cement as the same amount of sand.

I have found that if Trinidad pitch be first exhausted with petroleum ether and then with carbon disulphide, when the latter solution is evaporated there remains a brilliant black solid that cleaves from the vessel in thin scales. These scales are insoluble in petroleum ether, ethyl ether or alcohol, melted paraffine, and in fact most of the solvents of bitumen. They are wholly soluble in chloroform and benzole, and partially soluble in boiling spirits of turpentine, the portion insoluble appearing as a brown powder. If the scales are dissolved in benzole and petroleum ether added in large excess, a brown powder is precipitated that may be collected on a filter. When the powder is heated it becomes black and coheres. The portion soluble in spirits of turpentine may be wholly or partially precipitated, by an excess of petroleum ether, as a brown powder. When the solution of that portion soluble only in chloroform is evaporated and the residuum washed in ethyl alcohol, it appears as a brown powder without cohesion. These reactions show that the black scales obtained by the evaporation of the carbon disulphide solution above mentioned consist of a mixture of two, if not more, distinct substances. The first of these that is soluble in boiling spirits of turpentine is a very dense and exceedingly viscous fluid, possessed of great

tenacity, and it evidently plays a very important part in the cementing properties of Trinidad pitch. The portion that is only soluble in chloroform is a dark brown powder without cohesion, that does not melt when heated, but softens, becomes black, and at a red heat is decomposed, giving off a white vapor which takes fire and burns, leaving a carbonaceous residue that continues to burn at a red heat, leaving a small amount of ferruginous ash. It contained 5·87 per cent. of sulphur.

The chloroform soluble is not a constant constituent of asphaltum. Many asphaltums have not a trace of it; others have only a trace, while in others still, the percentage is very small. In those asphaltums in which the chloroform soluble is wanting, the percentage of turpentine soluble is often very small. There are no physical properties that serve to distinguish these asphaltums to the eye. The asphaltum that contains only a trace of chloroform soluble and but a small percentage of turpentine soluble may be in appearance a brilliant black, brittle solid, not to be distinguished by the eye from one that consists of from one-third to one-half of chloroform soluble. The relation of physical to chemical properties has not yet been determined.

It may be that the chloroform soluble represents, in some instances, that portion of the asphaltum that has been in some manner deprived of its hydrogen. This condition is not necessarily brought about by weathering, although it cannot be denied that weathered asphaltums almost invariably yield a comparatively large percentage of chloroform soluble. The following analysis of materials from the deposit at Trinidad furnishes a remarkable example of this fact. In the following table, No. 1 represents the average composition of the ten specimens of crude commercial lake and land pitch, analyzed by Miss Laura A. Linton. No. 2 is the average composition of two specimens of alteration products of Trinidad pitch, one of which came from the lake, and the other from outside of it. I have also similar material from the weathered portions of asphalt veins in California.

	No. 1. Per Cent.	No. 2. Per Cent.
Petroleum ether soluble	34·612	20·306
Turpentine soluble	12·375	17·843
Chloroform soluble	5·757	13·968
Total bitumen	52·744	38·981
Organic material not bitumen	11·098	9·706
Mineral matter	36·160	38·175
Total bitumen soluble in petroleum ether	65·660	38·981
" " " " turpentine	23·391	34·195
" " " " chloroform	10·925	26·824

The material of which the analysis is given in column No. 2 may be what Mr. Richardson has called "chocolate pitch." It is a light brown, pulverulent solid, in form somewhat columnar, like starch, and just as easily rubbed into a powder between the fingers. It contains nearly three times the percentage of chloroform soluble that occurs in the average commercial pitch. Somewhere between the chloroform soluble of 10·925 per cent., which is found in the average commercial pitch, and the 26·824 per cent. found in this alteration product, the Trinidad pitch loses its tenacity and becomes friable. Of course, as the chloroform soluble is increased, it must be at the expense of the other ingredients. The petroleum ether soluble in this case is only about one-half the proportion given in column No. 1, the ratio being 38·981 : 65·66. The ratio of the chloroform soluble to the total bitumen is, in No. 1, 1 : 9·163, and No. 2, 1 : 2·789. The investigation of these problems has only just been entered upon, but it is a research of vast importance, and must in time command attention.

When these figures were first developed, from the results of Miss Linton's analytical work, it was hoped that some satisfactory explanation of the peculiar properties of glance pitch might be deduced. The claim that glance pitch is geologically old pitch is found to be entirely erroneous. The following table shows the compositions of five pitches, all of which are supposed to be cretaceous or older :

Per cent. of petroleum ether soluble in total bitumen	No. 1, 25·4605
	" 2, 35·0870
	" 3, 38·0300
	" 4, 49·9590
	" 5, 51·0430
	" 6, 8·5106

Nos. 2, 5 and 6 are very brilliant glance pitch; the others are equally hard, but not as brilliant. The chloroform soluble varies in these from less than 1 per cent. in No. 6 to 32·5 per cent. in No. 4. Just as brilliant and hard glance pitch as any of these, I know to be a melted tertiary asphaltum, of which more than 75 per cent. is soluble in petroleum ether. Such discordant results, obtained from such a large number of asphaltums from widely different localities, have confirmed the opinion that the peculiar properties of glance pitch do not depend upon chemical composition, but are the result of the melting of the asphaltum.

Reviewing the results hereinbefore stated, a number of general conclusions may be drawn that are of interest in connection with the significance and value of technical analyses of solid bitumens and bituminous rocks.

In the reply that Captain Torrey makes to De Smedt, he refers to the sulphur content of asphaltum, and cites an article by O. Hesse (*Arch. d. Pharm.*). This reference has been made quite widely for some years. In attempting to verify it, I found that Oswald Hesse had been a frequent contributor to German scientific literature for about thirty years, but I cannot discover that he has ever published a word upon asphaltum. The article referred to is by Otto Helm, and is to be found in *Arch. d. Pharm.*, III, **18**, 396. Helm does not mention retine, petrolene or asphaltene; but he discusses the sulphur content of crude asphaltum. He does not definitely locate any of his specimens, and for this reason his work loses much of its value.

In the April number of *Paving* for 1894, De Smedt replied to the criticism of Captain Torrey. He makes some very sweeping statements, but he gives no authority for them. He does not give any references, nor are we informed whether his statements are based upon his own researches

or those of others. I have made a very careful search in the scientific periodical literature of the last thirty years and I can find nothing by others, nor does my own experience confirm the statements made in this article. I have never seen any positive evidence that free sulphur exists in Trinidad pitch. It is possible that it does. I am of the opinion that the cases are extremely rare where free sulphur is mixed with any bitumen.

De Smedt asserts that petrolene contains of sulphur 9·20 per cent., and that asphaltene contains of sulphur 12·89 per cent. Miss Linton's analysis shows grahamite to consist of practically 50 per cent. each of petrolene and asphaltene. This would give, according to De Smedt, 11·045 per cent. of sulphur in grahamite. A careful determination of the sulphur in the specimen of grahamite used by Miss Linton shows it to contain 0·6125 per cent. of that element. It also contained a small percentage of iron, which I did not determine. It is probable that this iron and sulphur are combined as pyrites, together forming about 1 per cent. of the mineral. Less than 1 per cent. of albertite is soluble in petroleum ether. The mineral is practically all asphaltene. According to De Smedt, it ought to contain 12·5 per cent. of sulphur. A very careful determination of the sulphur in albertite gave 0·2023 per cent., and not a trace of iron.

If De Smedt's figures were correct, a bitumen containing 90 per cent. of petrolene should contain 8·28 per cent. of sulphur, whereas such an one actually contained 1·5 per cent. Another, consisting of 70 per cent. petrolene and 30 per cent. asphaltene, should contain 10·3 per cent. of sulphur; such an one actually contained 7·5 per cent. I have never seen a bitumen that contained 10 per cent. of sulphur. These examples show that whatever may have been the basis from which De Smedt drew his conclusions, he was entirely mistaken according to the facts.

These names have figured in another role. In the testimony given in the trial of the well-known Peoria suit, it was asserted by several witnesses that petrolene was the cementitious portion of asphaltum, and also that residuum

oil was without cohesion, and that asphaltene was as inert as so much sand. They practically defined petrolene as that portion of an asphaltum that is soluble in petroleum ether. I have made many analyses, by solution, of street surfaces, some of which were well known to be very good, and some very bad. If the claim of these witnesses is correct, no one will dispute that the petroleum ether soluble—denominated petrolene in these cases—included whatever residuum oil might have been added to the Trinidad pitch to soften it, and would therefore lessen, by whatever its proportion might be, the cohesion (and also adhesion) of the original petrolene, for the other constituents of the mixture, including the inert asphaltene and sand. The amount of this petroleum ether soluble is surprisingly small. It rarely amounts to an average of more than 6 per cent., and is often less.

I do not question the intentional veracity of any of these witnesses. They were making assertions which they believed, and very much desired, should represent the truth, but in my judgment they were greatly mistaken. If street surfaces constructed of the "best pitch lake asphalt" are held together by *only* 5 per cent. or a little more of cementitious matter, it is not remarkable that they go to pieces in a few months, but that they hold together at all. The fact is that the cementitious principle of a street surface consists in the total amount and character of the bitumen that the surface mixture contains.

The danger of basing any general conclusions upon such reasoning as was employed by these witnesses can only be fully appreciated when it is recognized as a fact that the portions of different bitumens dissolved by petroleum ether have no necessary chemical identity, or even close resemblance, to each other; that they vary greatly in amount, in consistency, in tenacity, and many other physical properties. These facts being recognized as established beyond dispute, the question arises, of what value is a technical analysis of asphaltum by solution? The value lies *only* in analyses made with the same solvents under the same conditions, as a means of comparison, especially when applied to

different specimens from the same locality. The analyses should not only be made with the same solvent and in precisely the same manner, but the results should be reported in precisely the same manner, in order that direct comparisons may be made of them. It is the height of folly to attempt to compare things that are different or that are stated differently. When, therefore, Pacific Coast asphaltums are dissolved in a Pacific Coast petroleum ether, or in acetone, and anything is affirmed concerning them, as compared with Trinidad or Bermudez asphaltum that have been dissolved in ethyl ether or petroleum ether from Eastern petroleum, the analyst is wholly unfair and in the end defeats the purpose of analysis. Giving these unlike products the same arbitrary name only increases the confusion.

For these reasons we insist that a uniform method by the same solvents should be adopted by all those who are engaged in analyzing asphaltum.

In the article published in the March number of *Paving* for 1894, Captain Torrey says, in reference to the use of the names retine, petrolene and asphaltene: "With the present knowledge of them, it would be better not to use these misleading names, but others more appropriate." In this opinion I fully agree, and would add that for some time past I have sought to discard them, and to report the percentage soluble in petroleum ether and other solvents as "the petroleum ether soluble," and not as petrolene, etc.

NOTES CONCERNING RETENE, ETC.

[1] *Paving and Municipal Engineering*, Nov., 1893, p. 206.
[2] *Paving and Municipal Engineering, vide*, 1894.
[3] *Journal of the Franklin Institute*, **149**, 29.
[4] *See* Clifford Richardson, *Journal Soc. of Chem. Ind.*, **17**, 14.

ELEMENTARY GRAPHICS AND GEOMETRY OF THERMODYNAMICS.

By Robert H. Thurston.

Diagrams of Energy represent the method of variation of energy and of work in any system in which such variation occurs as a function of quantities of which the varying magnitudes may be represented graphically. These magnitudes are exhibited on such diagrams by the coördinates of points representing the condition of the substances, and their variations, by lines which are the loci of successive positions of those points.

Thermodynamic Diagrams exhibit the varying thermal states of a working substance, and the mechanical effect of thermal changes when heat-energy and mechanical energy are converted, the one into the other. In such diagrams, the coördinates usually, but not necessarily, measure pressures and volumes of the working fluid.

Thermal Lines are such as, in thermodynamic diagrams, exhibit the change of condition of the working substance. They are generally, in all applications of practical nature, lines of which the ordinates measure pressures and the abscissas measure volumes.

Isothermal Lines, or lines of equal temperature, are such as represent, on a diagram of energy, variations of pressure and volume occurring while the temperature of the substance remains unchanged. They have the equation $p\,v =$ constant when the working substance is a perfect gas.

Adiabatic Lines, or *Isentropic Lines*, are lines exhibiting variations of pressure and volume when the substance is caused to change its condition within a non-conducting vessel or chamber, no heat being permitted to enter or to leave it. They are "lines of no transmission of heat," and have the equation, for gases, $p\,v^{\gamma} =$ constant, in which v^{γ} is the ratio of the specific heat at constant pressure to that at constant volume. In all such operations, the "thermodyna-

mic function," and variation of entropy, the variation of heat per unit of temperature, are constant.

Isodiabatic Lines are sets of lines, two or more, along which equal quantities of heat are transferred to and from the working substance.

Isodynamic Lines are those which represent variations of volume, and of pressure, during which the total internal energy is retained constant, heat being supplied or rejected to compensate any loss by the expenditure of internal energy in doing external work or in wastes of heat. In other words, the sum of the actual energy of sensible heat and the potential energy due molecular relations of position is constant during any isodynamic change.

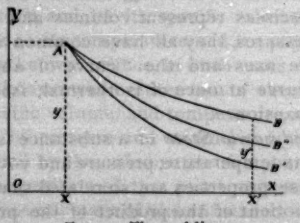

FIG. 1.—Thermal lines.

The Relation of the Thermal Lines is seen in the accompanying diagram of energy, *Fig. 1*.

Let *A B* be the isothermal line of a substance expanding from the pressure and volume *A x*, *O x*, to the pressure and volume *B x'*, *O x'*. An adiabatic line will fall below *A B*, as at *A B'*; since the temperature of the fluid is held constant, during isothermal expansion, *A B*, by supplying the quantity demanded for conversion into external and internal work, or mechanical energy; while, during adiabatic expansion, no heat is so transferred to the fluid, and its temperature, and therefore its pressure, must, in the latter case, fall. In the one case, all heat transformed into work is supplied from without; in the other case, such work must be done at the expense of the store of heat originally contained in the mass.

The adiabatics and isothermals approach each other the more closely as the temperature is reduced, and as less work is done in expansion, until, at absolute zero, all heat motion ceasing, they coincide with their common asymptotes, and coördinate axes.

The isodynamic line, *A B''*, falls between the isothermal and the adiabatic; since the heat demanded for the performance of interior work is, or may be, furnished by drawing upon the initial stock of sensible heat, while only enough must be supplied from without to do external work. With perfect gases, the isothermal and isodynamic lines are evidently coincident, since no internal work can be done in their expansion.

It is evident that all these thermal curves, being lines of which the abscissas represent volumes and the ordinates coincident pressures, they all have common asymptotes in the coördinate axes and the "curve of absolute cold,"* which is a curve at once of isothermal, isodynamic, and isentropic expansion.

The Thermodynamic State of a substance is its condition as related to its temperature, pressure and volume. In perfect gases these properties are so related that, for unity of weight, the quotient of the product of the pressure, p, and the volume, v, by the absolute temperature, T, is constant, *i.e.*,

$$\frac{p\,v}{T} = \text{constant.}$$

It thus follows that the state of the body is determined whenever either two of these three variable quantities is known. For isothermal expansion, $p\,v = \text{constant}$;

$$p \propto \frac{1}{v};$$

in isometric expansion, in which v is constant,

$$\frac{p}{T} = \text{constant},$$

and $p \propto T$; for isopiestic expansion, in which p is constant,

*So named by Rankine.

$$\frac{v}{T} = \text{constant},$$

and $v \propto T$. For adiabatic expansion, in which the total heat is invariable, except by transformation, $p\,v^{\gamma}$ constant, and

$$p \propto \frac{1}{v^{\gamma}}.$$

Proposition 1.—The thermodynamic state of any gaseous substance, and its variations, may be indicated by the positions of points on a diagram of energy, of which points the coördinates are measurable in terms of pressure and volume.

For, let the thermodynamic state of the given substance be such that its heat-energy is known and can be measured in units of work, and let its specific volume* and its pressure be known; its temperature and its physical condition are then fully known. Since, in such cases, the state of the substance is known when either two of the three variables, pressure, specific volume, and temperature, are known, it is fully defined by pressure and volume, and these quantities being measured by the coördinates of a point on a diagram of energy, the position of that point represents and defines the thermodynamic state of the substance.

The variation of the position of the point so defining the condition of a substance evidently exhibits the variation of such condition.

Corollary 1.—When the substance has a pressure and a volume due solely to the action of thermal energy, *e. g.*, a perfect gas, the coördinates of the point representing its physical state may be taken on a diagram of energy as measures of its actual pressure and volume; otherwise such coördinates in diagrams of energy may measure either the external pressure confining the fluid, or the internal forces, as of molecular attractions or repulsions, or the sum of external and internal forces, accordingly as it is proposed to measure variations of external, of internal, or of total work, during changes of condition.

*Specific volume is the volume of unity of weight.

Corollary 2.—A fluid possessing a fixed quantity of total energy, represented by a function of pressure, volume and temperature, may be represented by an indefinite number of points, each defining a relation of pressure and volume determined by the temperature of the substance in the assumed condition. Such points must all fall into a line, which may be called that of equal energy, a line which has already been denominated the isodynamic line.

Scholium 1.—A gaseous fluid of which the volume and pressure are defined solely by the quantity of heat-energy with which it is charged, and in which, consequently, the temperature is constant for equal energy, will, in such case, have a constant value for the product of pressure and volume; its isodynamic line has the equation $p\,v =$ constant. The isodynamic line of a perfect gas is, therefore, an equilateral hyperbola.*

Corollary 3.—The quantity of heat contained in the unit of weight of a perfect gas being measured by the product of its absolute temperature into its specific heat, when the temperature is constant, $p\,v =$ constant $= R\,T$ and the isothermal expansion line of a perfect gas is an equilateral hyperbola.

This is the law of Boyle and Marriotte.

Scholium 2.—The isothermal and isodynamic lines of the perfect gas are identical.†

Corollary 4.—The adiabatic, or isentropic, line of any fluid, as presented in a diagram of energy, falls below the isothermal line to an extent which measures the transformation of heat in doing the work of expansion; in its equation, $p\,v^{\gamma} =$ constant, therefore, γ, whether constant or variable, exceeds unity for the perfect gas and for all other fluids is greater than the value for isothermal expansion. If hyperbolic, these curves are, therefore, of a higher order of hyperbola than the equilateral.

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*This is approximately true for permanent gases, and for vapors far removed from their temperatures of liquefaction.

†They are nearly identical for permanent gases, and for vapors far removed from their points of liquefaction.

Proposition 2.—The total quantity of heat transformed by the expenditure of energy in the work of expansion of any fluid, against internal or external forces or both, and in thus doing internal or external work or both, is measured on a diagram of energy by the area included under the curve representing the changes of pressure and volume occurring while such expansion is in progress.

For, since in any such diagram the ordinates measure resistances and the abscissas are proportional to the spaces through which such resistances are exerted, the work done will be measured by summing the products of resistances into space, or integrating the differential areas between the limits of such expansion, and thus obtaining a measure of the area under the expansion line.

But, according to the first law of thermodynamics, the work so done is the equivalent of the quantity of heat transformed into mechanical effect during the operation. Hence, the area so measured is a measure of the total heat so transformed and of the total work so done.

Corollary 1.—When the work represented on the diagram is that done against external forces, the heat thus measured is the total amount transformed into external work; when the ordinates measure internal resistances, the heat measured is that transformed in doing internal work; when the ordinates measure total resistances, external and internal, the work and heat measured are the total work done and the total heat transformed in performing it.

Scholium 1.—The diagram of energy of a perfect gas always measures total work done, all such work being, in such a case, external; and the ordinates are proportional to the tension of the gas. The diagram for any other fluid may be of either class.

Scholium 2.—The specific heat of constant pressure is measured by the sum of the heat demanded to produce a change of temperature, unity, in a stated volume, and that required for transformation into total work, external and internal, as exhibited on diagrams of energy. The specific heat of constant volume is simply that demanded to produce change of temperature and is not dependent upon the nature

or method of variation of internal work; it is the *real* specific heat of the substance.

Proposition 3.—The total thermal and intrinsic energy which may be drawn upon in the performance of work by the expansion of a fluid is measured, on a diagram of energy, by the area included under the adiabatic curve, extended indefinitely in the direction of increasing volume from the point representing the initial state of the substance.

For, in the figure let $A\ B$ be the adiabatic, or curve of no transmission of heat, for a substance expanding from the initial state A, until, all its stock of heat-energy being expended, its temperature and its tension become zero, and its volume indefinitely large.

The work done, as measured on the diagram, according to the definition of the adiabatic line and the first law of thermodynamics, is performed at the expense of the initial stock of energy, but this work is the exact equivalent of the heat transformed, and is exactly measured by the area of the diagram of energy, $A\ B \ldots . X\ x_1\ A$, included between the curve and the ordinate y_1 and the base $O\ X$.

Hence, this area measures the heat originally available in the state A, for transformation into mechanical energy or work.

Corollary 1.—When the ordinates of the adiabatic curve measure the external pressure, as always with perfect gases, and usually with other fluids, the diagram represents the external work performed; when representing internal resistance to expansion, due to cohesion, or molecular attractions, the work measured is similarly wholly internal; when measuring the sum of the two resistances, the diagram represents total internal and external work obtainable by total transformation of heat.

Proposition 4.—The energy transformed from the thermal to the mechanical condition during any limited, adiabatic, change of state is measured, on a diagram of energy, by the area included under the adiabatic line passing through the two points representing the initial and final states of the substance, and between the ordinates of those points. This quantity thus measures the total loss of heat by the expanding fluid.

For, in the figure, the areas $A\,A'\,B\,\ldots\ldots\,X\,x_1\,A$, and $A'\,B\,\ldots\,X\,x_2\,A'$, measure, respectively, the energy available in the two states, $A\,A'$; the difference can only have been expended in the production of work measured by the difference of those areas, $A\,A'\,x_2\,x_1\,A$, which, therefore, is a measure of the heat so transferred and transformed, and thus lost or gained by the substance by expansion or compression.

Proposition 5.—The quantity of sensible heat gained or lost by a fluid in passing from one state to another without change of volume is represented on a diagram of energy by the area included between two adiabatic or isentropic lines of indefinite extent, and the ordinate common to the two points representing the initial and terminal states.

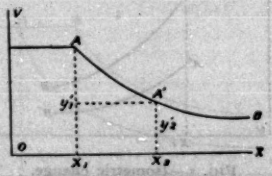

FIG. 2.—Stored heat.

For, in *Fig. 3*, the thermal energy of the body, or its sensible heat, in either of the two states, as A or A', is measured by the area of the diagram under the adiabatic, indefinitely prolonged toward X, as $A\,B\,\ldots\,X\,x\,A$, and $A'\,B'\,\ldots\,X\,x^1\,A'$; and the difference of those areas, $A\,B\,\ldots\,X\ldots\,B'\,A'\,A$, must, therefore, measure the difference of thermal energy and the heat gained or lost in passing from the one state to the other.

Scholium 1.—The total amount of heat received or surrendered by any substance, in passing from one state to another, is the sum of the quantities demanded for transformation into work, as shown on the diagram of variation of total work or energy, other than thermal, and that required to produce thermometric changes and consequent changes of pressure. The total amount of heat gained or lost, received

or rejected, during any change, is thus determined by the method of expansion or compression of the fluid.

Scholium 2.—The quantity of heat lost or gained during such changes as occur isometrically cannot be measured on a diagram of energy which simply exhibits that change.

Scholium 3.—No change, by transformation of heat into mechanical energy, or productive of mechanical work, can occur isometrically, but must be produced by changes of volume.

Proposition 6.—The quantity of heat absorbed, and the quantity transformed into work or energy, during isothermal change, is measured, on a diagram of energy, by the area included under the isothermal expansion line and between the

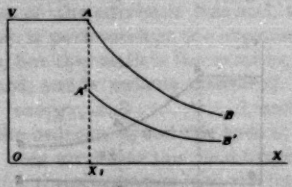

FIG. 3.—Isometric change.

ordinates of the two points representing the initial and terminal states of the body; the diagram measuring the total work done, both exterior and interior; its ordinates being taken to measure total pressure.

For, in *Fig. 2*,* assuming *A B* to represent an isothermal line traversing *A* and *A'*, the ordinates of the curve measuring the sum of external pressure and internal attraction, should the fluid not be a perfect gas, the total work done during the change is measured by the area $A\,A'\,x_2\,x_1$. This is also the equivalent of the heat transformed into work. But, the temperature remaining constant, no other change demanding accession of heat occurs, and the quantity so measured is a measure of the heat absorbed by the substance during such an isothermal change.

* Figure in Proposition 3.

Scholium.—The area included between a pair of adiabatic lines, similarly drawn from a common initial to a common terminal ordinate, measures the difference in the amount of external work which may be done by transformation of heat, in consequence of the isometric change of condition between the initial points on the two lines; internal work being obviously the same in both cases.

Proposition 7.—When change of volume occurs at constant pressure—*i. e.*, during isopiestic changes—the total amount of heat absorbed or emitted by the working substance is equal to the sum of the amounts demanded to produce change of temperature and for transformation into work; the increment of heat demanded for each of the two changes is constant, and the flow of heat is directly proportional to

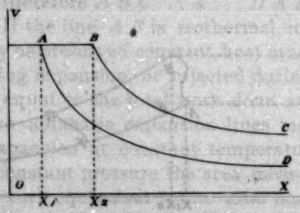

FIG. 4.—Isopiestic change.

the variation of area of the diagram representing the change, and to the variation of volume.

For, let the alteration of volume occur between A and B, and at the constant pressure $A\,x_1$. Let $A\,D$, $B\,C$, be a pair of adiabatics, drawn from A and B indefinitely toward X. Then, during such an isopiestic change, the variation of energy will be measured by the area $A\,D\,\ldots\,X\,\ldots\,C\,B\,A$, while the work done under the pressure $x_1\,A$ will be measured by the area $A\,B\,x_2\,x_1\,A$; and the total variation of heat by absorption during expansion, or by emission during compression, will be measured by these two quantities.

Since the areas are similar and are proportional to their measures on the axis of abscissas, their altitude remaining constant, the influx or efflux of heat, being proportional

to the energy so represented, must occur at a rate directly proportional to the rate of change of volume of the working substance and of these areas.

Corollary.—The coëfficient for specific heat at constant pressure is thus constant for elastic fluids.*

Proposition 8.—The total quantity of heat absorbed or emitted by any fluid, in passing from any one condition, such as may be represented on a diagram of energy, to another, is measured by the area included between the line representing the change and a pair of adiabatic or isentropic curves drawn from its extremities, indefinitely, in the

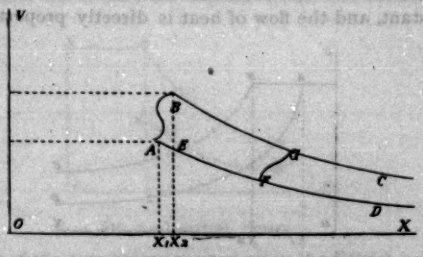

FIG. 5.—Rankine's principle.

direction of increasing volume, and until they become asymptotic with the axis of volumes.

For, in *Fig. 5*, let this change take place between *A* and *B*. Then the work done may be represented by $A\ B\ x_2\ x_1$, and the variation of thermal energy by $A\ B\ C \ldots X\ D\ A$; since $E_1 = A\ D \ldots X\ x_1\ A$, is the energy of the mass at *A*, and $E_2 = B\ C\ X\ x_2\ B$ is that at *B*; while $E_3 = A\ B\ x_2\ x_1\ A$, is the work done in the change, and $E_4 = E_2 + E_3 - E_1 = A\ B\ C \ldots X \ldots D\ A$, is the measure of the net variation of heat-energy, which amount must be supplied during expansion or withdrawn during compression.

*This was shown by Carnot (1824), by deduction from thermodynamic principles, and experimentally, by Regnault.

Or, let the mass expand along $B\,C$ until its stored energy is expended in work; then compress the fluid until it passes adiabatically to A, and thence back to B, the transfer from the adiabatic $B\,C$ to the adiabatic $C\,A$ being thus effected without measurable variation of heat-energy. The net work performed during this operation is measured by the area between the two adiabatics and the original path $A\,B$, and this area is therefore the measure of the total heat demanded or rejected.* More explicitly, the work done during expansion from A to B is measured by the area $A\,B\,x_2\,x_1\,A$; that equivalent to the stored energy at B is measured by $B\,C\ldots X\ldots x_2\,B$; while that originally stored at A is measured by $A\,D\ldots X\,x_1\,A$. The net amount, measuring the total of all heat demanded during the operation, is therefore $A\,B\,C\ldots X\ldots D\,A\,B$ as before.

Scholium 1.—If the line $A\,B$ is isothermal, in order that temperature may be preserved constant, heat must evidently be supplied during expansion, or rejected during compression, in amount equal to the total work done, and the area between the two adiabatic expansion lines measures the latent heat of expansion at constant temperature. When $A\,B$ is a line of constant pressure the area measured is proportional to the work equivalent to the total heat of expansion under constant pressure.

Scholium 2.—Since the thermal state of a body depends on its actual physical condition, and not upon the method of attaining that condition, the difference between the total heat absorbed or emitted and the work done in any change is dependent solely upon its initial and final states, and is entirely independent of the method of change, *i. e.*, of the form of the curve or path $A\,B$.

Scholium 3.—The quantity of work done during any change, as $A\,B$, is variable with the method of producing the change, as represented by the curve; whence the total heat demanded or emitted during such change is dependent upon the method of variation. An infinite number of paths may be taken between A and B, no two of which will pro-

*This is substantially the demonstration of Rankine; "Steam Engine," p. 303.

duce the same total variation of heat-energy in the system, while the difference of intrinsic or stored energy may be the same for all.

Scholium 4.—Since the internal work during any change, *A B*, is precisely the same for a definite change of volume, however produced, the internal work done along the line *A B C . . . . X* is equal to that done along the line *A D . . . . X*, and the difference of area *A B C . . . . X . . . . D A* is independent of internal work, and the proposition applies equally to perfect gases and to other fluids.

Corollary 1.—Two points being taken in each of two adiabatic lines, as *A* and *F*, *B* and *G*, the difference in the quantity of heat absorbed or emitted in transfers by the two routes *A B*, *F G*, from adiabatic to adiabatic, is measured

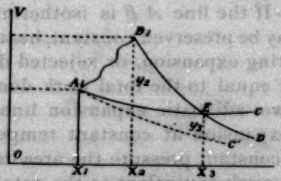

FIG. 6.—Heat absorption.

by the area *A B G F*, included between the two adiabatics and the two lines indicating the two routes and marking the method of change; this area measures work done, equivalent in amount to the difference in quantity of heat so transferred and transformed into work, and that retransformed into heat.

Corollary 2.—The two routes of transfer being isothermal, the difference in quantity of heat absorbed or emitted is measured by the area included between the two isothermals and the two adiabatic lines.

Corollary 3.—Transfer from adiabatic to adiabatic being effected along lines of constant pressure or lines of constant volume, the areas included between the pair of adiabatics and the pair of isopiestic or of isometric lines measure the difference in quantity of heat transferred.

Proposition 9.—The total quantity of heat absorbed or emitted by a substance, in passing from one condition to another, such as may be represented on a diagram of energy, is measured by the area included under the line representing such change and an adiabatic curve drawn from the upper extremity of that line to the point of intersection of the adiabatic with the isodynamic line, from the other extremity of the curve representing the change. *Fig. 6.*

Let $A\ B$ be the line of transfer from the state A to the state B. Draw from A the isodynamic line $A\ C$, meeting the adiabatic from B at E. The curve $B\ D$ then represents the method of variation of pressure and volume when no heat is absorbed by, or emitted from, the fluid, during change of volume; while the curve $A\ C$ represents the variations of pressure and volume when its internal energy does not change.

Then will the total variation of heat, by absorption or emission, during the change $A\ B$ be measured by the area, $A\ B\ E\ x_3\ x_1\ A$, included between the lines $A\ B$, $B\ E$, and the ordinates to A and B.

For, (1)—The lines $B\ D$, $A\ C$, must intersect; since heat is supplied along the line $A\ C$, to preserve the original stock of internal energy while work is done by expansion; and during expansion along $B\ D$, no heat is added, and pressure must therefore diminish more rapidly along $B\ D$ than along $A\ C$, and, at some point, E, they thus intersect, the pressure and volume becoming the same for both lines, and the internal energy at E being equal to that at A.

(2) The total heat furnished along $A\ B$ is the sum of that demanded to perform work and that required to produce variation of internal energy; the first is measured by the area $A\ B\ x_2\ x_1\ A$; the second is measured by the area $B\ E\ x_3\ x_2\ B$, since the work so measured is performed by the surplus of heat supplied along $A\ B$ over that demanded to do the work of expansion; at E all internal energy so gained between A and B has been transformed into work. Hence the heat absorbed during the change $A\ B$, or emitted during the change $B\ A$, is measured by the equivalent work under the lines $A\ B$ and $B\ E$.* Q. E. D.

*This use of the isodynamic line is due to Cazin.

Scholium 1.—The area under $A\ B$, $B\ E$, as above, is equal to that included between two isentropic lines $A\ C$, $B\ D$, extending from A and B, indefinitely, in the direction of increasing volume.

Scholium 2.—When the line $A\ B$ is isothermal, the area measured as above is proportional to the latent heat of expansion at constant temperature.

Scholium 3.—If the line $A\ B$ is a line of constant pressure, the heat so determined measures the total heat of expansion at constant pressure.

Scholium 4.—If $A\ B$ is a line of constant volume, the total heat of expansion at constant volume is obtained.

Scholium 5.—If $A\ B$ is adiabatic, no heat is absorbed or emitted, the measured area becoming zero, and if $A\ B$ is isodynamic, all heat absorbed or emitted is that transformed from or into work; the total area measured is proportional to that work.

Corollary 1.—The area $B\ E\ x_3\ x_2\ B$ measure the equivalent of so much of the heat gained or lost by the body, during the change $A\ B$, as escapes transformation into work.

Proposition 10.—The internal energy gained or lost by a body, by a process of change represented, on a diagram of energy, by any line, as $A\ B$, is measured by the area included between an isentropic (adiabatic) line passing through the higher terminal, B, of that line, and the base-line, and limited by ordinates passing through that point, and through the intersection of that isentropic line with the isodynamic curve drawn through the other terminal of the path of transfer.

Let $A\ B$, *Fig. 6*, represent the route by which the substance is transferred from the state A to the state B, or the reverse. Then will the area, $B\ E\ x_3\ x_2\ B$, included between the isentropic line $B\ E$, and the base, $x_2\ x_3$, measure the internal energy gained or lost between A and B.

For, the total heat absorbed is measured by $A\ B\ E\ x_3\ x_1\ A$, of which the quantity $A\ B\ x_2\ x_1\ A$, only, is expended in external work; the remainder, $B\ E\ x_3\ x_2\ B$, must therefore measure the heat transferred in producing the variation of internal energy.

Scholium.—If the body is gaseous, the isodynamic line is also isothermal, and the area above measured is then proportional to the heat transferred without conversion, producing variation of temperature, *i. e.*, kinetic energy of molecules; and this area measures also the latent heat of expansion.

[*To be concluded.*]

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, December 19, 1900.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 19, 1900.

President JOHN BIRKINBINE in the chair.

Present, 58 members and visitors.

Additions to membership since last report, 48.

The Actuary reported from the meeting of the Board of Managers held Wednesday, December 12th, a preamble and series of resolutions making formal protest against the adoption, by the Trustees of the Franklin Fund of the city of Boston, of the name of the Franklin Institute to designate an institution of the applied sciences, which it is designed to found in Boston with the proceeds of this fund.

The President gave some explanations respecting the origin of this fund, and of a similar fund in Philadelphia, and stated that correspondence had been opened by the Secretary, under the instructions of the Board, with his Honor, the Mayor of the city of Boston, with the view of making the protest effective.

Mr. Louis E. Levy, delegate of the Institute to the Paris Exposition, presented his report, which covered substantially an account of the proceedings of the Congress of Associations of Inventors.

Mr. Joseph L. Ferrell, of Philadelphia, gave an account of the development of the art of fireproofing wood, with especial reference to the method and apparatus of the United States Fireproof Wood Company.

On Mr. Levy's motion, the subject was referred to the Committee on Science and the Arts.

The paper of Mr. Ferrell was discussed by Dr. S. P. Sadtler, Dr. Wahl, Mr. Joseph Richards and Mr. Wm. McDevitt.

The following nominations were then made in conformity with the by-laws:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	GEO. V. CRESSON.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" one year)	SAMUEL SARTAIN.
" *Auditor*	(" three years)	JNO. GEORGE COPE.

For Managers (to serve three years).

DANIEL BAUGH,
ROBT. C. H. BROCK,
STEPHEN GREENE,
HENRY HOWSON,
ALFRED C. HARRISON,
HENRY R. HEVL,
ALEX. KRUMBHAAR,
C. HARTMAN KUHN.

In place of SAMUEL F. HOUSTON (resigned),
BENJAMIN SMITH LYMAN.

For Members of the Committee on Science and the Arts (to serve three years).

L. L. CHENEY,
JAMES CHRISTIE,
G. H. CLAMER,
J. M. EMANUEL,
J. LOGAN FITTS,
FRANCIS HEAD,
CHAS. A. HEXAMER,
J. Y. MCCONNELL,
WM. MCDEVITT,
L. F. RONDINELLA,
ARTHUR J. ROWLAND,
SAMUEL SARTAIN,
T. CARPENTER SMITH,
THOMAS SPENCER,
JOHN C. TRAUTWINE, JR.

The President named the following members to serve as tellers of the annual election, to be held on Wednesday, January 16, 1901, between the hours of 4 to 8 o'clock P.M., viz.: Jas. H. Carpenter, Richard Gilpin, Wm. O. Griggs, F. M. Sawyer, Harrison Souder, C. Walton Swoope, Warner Walter.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, December 5, 1900.*]

MR. H. R. HEVL in the chair.

The following report was adopted:

(No. 2122.) *Reconstructed Granile as an Insulating Material for Electrical Uses.*—The Reconstructed Granite Company, New York. (Referred to the Committee by the Bureau of Awards of the National Export Exposition.)

ABSTRACT.—Reconstructed Granite is a manufactured product made substantially as follows: Chips of natural granite are calcined by being subjected to a high temperature and afterwards pulverized. The material is then thoroughly mixed with ground feldspar and kaolin, enough water is added to make the mixture plastic, and it is then moulded into the desired forms under heavy pressure. After being dried it is subjected to a temperature sufficient to cause the incipient fusion of the silicates present. When in-

tended to be used for electrical purposes the surface is given a vitrified glazing which increases its insulating qualities by rendering the mass much less porous, and consequently more impervious to moisture.

It is claimed for this product, in respect of its adaptability for electrical uses, that it is absolutely fire-proof; that it resists the action of all solvents and acids except hydrofluoric acid (which attacks it superficially); that it is frost-proof; that it is impervious to moisture. and that it has high insulating qualities.

A series of tests made by the investigators to determine the validity of these claims established the fact that the material is substantially fire-proof, acid-proof and water-proof. No test of its frost-proof qualities was made.

The average of several results gave the material a crushing strength of about 10,000 pounds per square inch, and a tensile strength of about 950 pounds per square inch.

Careful tests of the electrical insulating qualities of this product confirmed the claims of the manufacturers. As the result of their tests, the investigators report that "the ohmic resistance of the samples is very high."

Reference is also made in the report to the successful employment of this product for third-rail insulation, and for various applications in railway equipment.

From the tests made by the committee's investigators, and the testimony submitted, the conclusion is announced that reconstructed granite possesses distinct advantages for many forms of application as a material for electrical insulation. The award of the John Scott Legacy Premium and Medal is recommended to the inventors, Thos. Wilkinson Blakey, of Keene, N. H., and Wm. Courteney, of New York. [*Sub-Committee.*—Geo. A. Hoadley, Chairman; C. H. Bedell, Arthur J. Rowland, Wilbur M. Stine.]

The following passed first reading:

(No. 2107.) *Grate Bars.*—James Reagan, Philadelphia. (Referred by the Bureau of Awards of the National Export Exposition.) This report was referred back to the sub-committee, to investigate an alleged anticipation of Mr. Reagan's invention.

(No. 2124.) *The Facer Forged-Steel Car and Locomotive Wheel Company's Wheel.*—Philadelphia.

(Nos. 2145-2146.) *Method of Compressing Air by the Direct Action of Water. Raising Water by Means of Compressed Air.*—Jos. P. Frizell, Boston, Mass.

(No. 2154.) *Improvement in Light-Projecting Glasses.*—American Prismatic Light Company, Philadelphia.

(No. 2159.) *Surface-Grinding Machine.*—Gustav R. Landman, Philadelphia.

(This report was made advisory.) W. H. W.

SECTIONS.

(*Abstracts of Proceedings.*)

SECTION OF PHOTOGRAPHY AND MICROSCOPY.—*Stated Meeting*, held Thursday, December 6th. Dr. Henry Leffmann in the chair.

Mr. Theo. D. Rand presented a communication on the "Microscopic Structure of the Rocks of the Philadelphia Section," which was freely illustrated with the aid of thin sections, projected on the screen with the lantern-microscope.

F. M. SAWYER,
Secretary.

ELECTRICAL AND CHEMICAL SECTIONS.—*Joint Meeting*, held Thursday December 20th. Mr. Joseph Richards in the chair.

Mr. Chas. J. Reed read the paper of the evening on "Electro-Chemical Action," which was illustrated freely with the lantern, the blackboard, and experiments. Discussed by Dr. Joseph W. Richards, Mr. Carl Hering, the author and others. Referred for publication in full. The presiding officer expressed the thanks of the meeting to the author.

RICHARD BINDER,
Secretary.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, held Wednesday, December 12, 1900. Mr. Joseph Richards in the chair.

After the transaction of formal business, Mr. Charles Morris, of Philadelphia, read a communication on "Subterranean Waters." Discussed by Prof. F. L. Garrison, Dr. Henry Leffmann, Mr. J. C. Trautwine, Jr., Mr. James Christie and the author. (The paper was referred to the Committee on Publications.)

The meeting passed a vote of thanks to the speaker for his interesting contribution.

Mr. Edwin S. Balch gave an account of a curious occurrence of a soft calcium carbonate in a small cave located near North Dorset, Vermont, which he had visited. This material was found lining the walls of the cave, and could cut away with a knife like so much cheese. When dry the substance became pulverulent. It was found on analysis to be calcium carbonate.

The same speaker exhibited a photograph of an interesting natural bridge of marble occurring in a marble quarry near North Adams, Mass.

Adjourned.

WM. H. WAHL,
Secretary pro tem.